DESCRIPTION

[Title of Invention]

MAGNETIC-DISK GLASS SUBSTRATE, MAGNETIC DISK, MAGNETIC-DISK DRIVE DEVICE

[Technical Field]

[0001] The present invention relates to a magnetic-disk glass substrate, a magnetic disk and a magnetic-disk drive device.

[Background Art]

[0002] Nowadays, a personal computer, a digital versatile disc (DVD) recorder, and the like have a built-in hard disk drive (HDD) for data recording. In particular, a magnetic disk in which a magnetic layer is provided on a glass substrate is used in a hard disk drive that is used in a device premised on portability, such as a notebook-type personal computer, and magnetic recording information is recorded on or read from the magnetic layer with a magnetic head floating slightly above the surface of the magnetic disk. At this time, the rotation rate of the magnetic disk is about 5400 rpm, for example. A glass substrate having a higher rigidity and a higher impact resistance than a metal substrate (aluminum substrate) or the like is preferably used as a substrate of the magnetic disk. It should be noted that the magnetic-disk glass substrate generally has a thickness of 0.635 mm or 0.8 mm in a 2.5-inch magnetic disk, for example.

[0003] On the other hand, demand for impact resistance of a magnetic disk used in a stationary server device such as a network server device is not high because dropping the device need not be taken into consideration, and therefore, an inexpensive aluminum substrate has been conventionally used for that magnetic disk. For example, Patent Literature 1 discloses a magnetic-disk aluminum substrate having a thickness of 0.635 to 1.27 mm. However, in recent years, there has been demand for a magnetic-disk drive device used in a

server device with a magnetic disk rotated at a higher rotation rate (e.g., 15000 rpm) than the conventional one (e.g., 10000 rpm) in order to further improve the access time and the transfer rate. For example, when rotated at a high rotation rate of 15000 rpm or more, a conventional magnetic-disk aluminum substrate does not have enough rigidity even if the thickness is increased, and therefore, fluttering occurs. Accordingly, the use of a glass substrate having a high rigidity instead of an aluminum substrate is being studied.

[Citation List]

[Patent Literature]

[0004] [PLT1]: JP 2004-145928A

[Summary of Invention]

[Technical Problem]

[0005] Incidentally, when a magnetic disk was produced using a relatively thick glass substrate so as to prevent fluttering and a magnetic-disk drive device for a server device was manufactured using that magnetic disk, it was confirmed that particles are sometimes generated from the magnetic disk. Accordingly, it is an object of the present invention to provide a magnetic-disk glass substrate, a magnetic disk and a magnetic-disk drive device in which no fluttering of the magnetic disk occurs when the magnetic disk is rotated at a high rotation rate and particles are not likely to be generated during manufacturing.

[Solution to Problem]

[0006] As a result of intensive research by the inventors of the present invention to find out the cause of the above-described particles, it was found that the cause of the generation of the particles during manufacturing of a magnetic-disk drive device for a server device is that the magnetic disk is frequently removed from and reattached to the spindle of the magnetic-disk drive device. That is, it is thought that the cause is as follows.

[0007] A server device is a stationary type as described above. Since demand for a server device with a larger storage capacity is high while demand for

portability and space-saving properties is low, a large number of magnetic disks (for example, about five to ten magnetic disks) are sometimes provided in one magnetic-disk drive device. Moreover, in order to increase the yield of the magnetic-disk drive device during manufacturing, magnetic disks having unfavorable characteristics are replaced (repaired or reworked) by hand or machines after the magnetic-disk drive device is once assembled. These repairs are sometimes repeated several times. When a large number of magnetic disks are provided in one server device as described above, the magnetic disks need to be frequently removed from and reattached to the spindle of the magnetic-disk drive device. When a magnetic disk is removed from and reattached to the spindle, the side wall surface of the inner hole of the magnetic disk is rubbed against the spindle, and thus particles are generated. The components of the particles are the material of the spindle (such as aluminum and stainless steel) and/or the glass material and the film material of the magnetic disk. Since glass is a very hard material, the surface of the spindle is sometimes scraped. Also, since glass is a brittle material, the glass is sometimes chipped due to being rubbed against the spindle.

In particular, when the thickness of the magnetic disk is made larger in order that no fluttering occurs when the magnetic disk is rotated at a high rotation rate of 15000 rpm or more, for example, the length in the thickness direction of the side wall surface of the inner hole of the magnetic disk is increased. Therefore, the magnetic disk is likely to be rubbed against the spindle during the assembly of the magnetic disk to the spindle and during the above-described repairs, and thus the particles are more likely to be generated.

[0008] The particles that have been generated on the side wall surface of the magnetic disk sometimes subsequently move and attach to the main surface of the magnetic disk, and thus cause malfunction of the magnetic-disk drive device. It is thought that the cause of the malfunction is as follows. That is, a server device operates basically continuously, and therefore, the magnetic head continuously performs a seek operation in a magnetic-disk drive device

provided in the server device. It was found that a lubricant on the magnetic disk, the scraped-off protection layer and the like gradually attach to the particles on the main surface of the magnetic disk due to the continuous seek operation, and thereby, the particles may grow mainly in an in-plane direction of the substrate and form flat impurities having a diameter of about several micrometers. The presence of these large impurities causes contamination on the magnetic head, and thus causes reading errors and/or writing errors in the magnetic disk.

It should be noted that the acceleration of the magnetic disk and airflow caused by the rotation of the magnetic disk increase due to the rotation of the magnetic disk at a high rotation rate, and therefore, it is thought that the particles generated on the side wall surface of the magnetic disk more easily move to the main surface of the magnetic disk compared with a case where the magnetic disk is rotated at a low rotation rate. In addition, the relative speed (or collision energy) when the magnetic head comes into contact with the particles moved to the main surface of the magnetic disk increases due to the rotation of the magnetic disk at a high rotation rate, and therefore, it is thought that reading errors and/or writing errors in the magnetic disk are more likely to become apparent compared with a case where the magnetic disk is rotated at a low rotation rate.

[0009] As a result of further intensive research by the inventors of the present invention in view of the foregoing problems, it was found that by providing a recessed portion in the side wall surface constituting the inner hole of the magnetic-disk glass substrate, it is possible to reduce the contact area of the side wall surface constituting the inner hole of the magnetic-disk glass substrate and the spindle, and thus suppress rubbing of the magnetic disk against the spindle while securing a desired thickness with which no fluttering occurs when the magnetic disk is rotated at a high rotation rate.

[0010] That is, a first aspect of the present invention is a magnetic-disk glass substrate having a doughnut shape including a pair of main surfaces, two side

wall surfaces constituting an inner hole and a contour, and chamfered surfaces between the main surfaces and the side wall surfaces, in which the side wall surface constituting the inner hole has a recessed portion.

[0011] In the magnetic-disk glass substrate, the side wall surface constituting the inner hole may include a surface orthogonal to the main surfaces.

[0012] The magnetic-disk glass substrate preferably has a thickness of 1.0 mm or more.

[0013] In the magnetic-disk glass substrate, it is preferable that the side wall surface that constitutes the inner hole and includes the recessed portion has a length in a thickness direction of 0.7 mm or more.

[0014] In the magnetic-disk glass substrate, it is preferable that the side wall surface constituting the inner hole has a length in a thickness direction excluding the recessed portion of 0.8 mm or less.

[0015] In the magnetic-disk glass substrate, it is preferable that the surface of the recessed portion is polished so as to be a mirror surface.

[0016] In the magnetic-disk glass substrate, it is preferable that a recession of the recessed portion has a maximum depth of 50 μm or less.

[0017] In the magnetic-disk glass substrate, it is preferable that the recessed portion is formed over the entire circumference of the side wall surface.

[0018] A second aspect of the present invention is a magnetic disk having at least a magnetic layer formed on the magnetic-disk glass substrate.

[0019] A third aspect of the present invention is a magnetic-disk drive device including the magnetic disk, a spindle for fixing the magnetic disk, and a magnetic head.

[Brief Description of Drawings]

[0020] FIG. 1A is a drawing illustrating the shape of a magnetic-disk glass substrate according to an embodiment.

FIG. 1B is an enlarged view of a cross-section taken along line X-X shown in FIG. 1A.

FIG. 2 is a drawing illustrating a method for forming a recessed portion

in a side wall surface constituting an inner hole of a magnetic-disk glass substrate according to an embodiment.

[Description of Embodiments]

[0021] Hereinafter, a magnetic-disk glass substrate of the present embodiment and a method for manufacturing the magnetic-disk glass substrate will be described in detail.

[0022] [Magnetic-disk glass substrate]

Aluminosilicate glass, soda-lime glass, borosilicate glass, or the like can be used as a material for a magnetic-disk glass substrate of this embodiment. In particular, aluminosilicate glass can be preferably used because it can be chemically strengthened and be used to produce a magnetic-disk glass substrate that is excellent in the flatness of its main surfaces and in the strength of the substrate. Amorphous aluminosilicate glass is more preferable.

[0023] Although there is no limitation on the composition of the magnetic-disk glass substrate of this embodiment, the glass substrate of this embodiment is preferably amorphous aluminosilicate glass that contains, in terms of oxide amount in mol%, SiO_2 in an amount of 50 to 75%, Al_2O_3 in an amount of 1 to 15%, at least one component selected from Li_2O, Na_2O and K_2O in a total amount of 5 to 35%, at least one component selected from MgO, CaO, SrO, BaO and ZnO in a total amount of 0 to 20%, and at least one component selected from ZrO_2, TiO_2, La_2O_3, Y_2O_3, Ta_2O_5, Nb_2O_5 and HfO_2 in a total amount of 0 to 10%.

[0024] FIG. 1A and FIG. 1B show the shape of a magnetic-disk glass substrate G of this embodiment. FIG. 1A is a plan view of the magnetic-disk glass substrate of this embodiment. FIG. 1B is an enlarged view of a cross-section taken along line X-X shown in FIG. 1A.

As shown in FIG. 1A, the magnetic-disk glass substrate G of this embodiment has a doughnut shape that is provided with a circular inner hole and has an annular contour. As shown in FIG. 1B, the magnetic-disk glass

substrate G of this embodiment has a pair of main surfaces 11p and 12p and two side wall surfaces that constitute the inner hole and the contour. In FIG. 1B, the side wall surface constituting the inner hole is a side wall surface 10w and has a recessed portion 10h. The recessed portion 10h is formed over the entire circumference of the side wall surface 10w. Chamfered surfaces 11c and 12c are respectively formed between the pair of main surfaces 11p and 12p and the side wall surface 10w. The angle formed by the main surface 11p and a linear portion of the chamfered surface 11c (chamfering angle: θ) is, for example, 40° to 70°. Similarly, the angle formed by the main surface 12p and a linear portion of the chamfered surface 12c (chamfering angle) is also, for example, 40° to 70°. It should be noted that the chamfered surfaces 11c and 12c may have a round shape that projects outward.

It is preferable that the side wall surface 10w constituting the inner hole includes a surface orthogonal to each of the two of main surfaces 11p and 12p. The side wall surface may be constituted by a surface projecting outward, but it is generally thought that when the magnetic-disk glass substrate in which the side wall surface is largely constituted by a surface orthogonal to the main surfaces is provided in a magnetic-disk drive device, the side wall surface is brought into smooth contact with the spindle, and therefore, such a structure is preferable for the achievement of the functions and effects of the present invention.

[0025] In the cross-sectional shape shown in FIG. 1B, t1 denotes the length of the straight line that joins the intersection of a virtual line obtained by extending the linear portion of the chamfered surface 11c and a virtual line obtained by extending the straight line of the side wall surface 10w, and the intersection of a virtual line obtained by extending the curved portion of the recessed portion 10h toward the main surface 11p side and the virtual line obtained by extending the straight line of the side wall surface 10w. t2 denotes the length of the straight line that joins the intersection of a virtual line obtained by extending the linear portion of the chamfered surface 12c and

a virtual line obtained by extending the straight line of the side wall surface 10w, and the intersection of a virtual line obtained by extending the curved portion of the recessed portion 10h toward the main surface 12p side and the virtual line obtained by extending the straight line of the side wall surface 10w. t3 denotes the length of the straight line that joins the intersection of a virtual line obtained by extending the curved portion of the recessed portion 10h toward the main surface 11p side and a virtual line obtained by extending the straight line of the side wall surface 10w, and the intersection of a virtual line obtained by extending the curved portion of the recessed portion 10h toward the main surface 12p side and the virtual line obtained by extending the straight line of the side wall surface 10w.

[0026] Although there is no limitation on the size of the magnetic-disk glass substrate G of this embodiment, the magnetic-disk glass substrate G may have a nominal diameter of 2.5 inches, for example. The magnetic-disk glass substrate G of this embodiment is preferably used for a magnetic disk to be integrated in a magnetic-disk drive device for a server device. The magnetic disk for a server device is rotated at a high rotation rate of, for example, 15000 rpm or more, and it is required to secure a desired thickness, for example, a thickness of 1.0 mm or more, with which no fluttering occurs during such rotation at a high rotation rate. Moreover, the length in the thickness direction (L in FIG. 1B) of the side wall surface 10w including the recessed portion 10h is 0.7 mm or more.

[0027] By providing the recessed portion 10h in the side wall surface 10w constituting the inner hole of the magnetic-disk glass substrate G of this embodiment as shown in FIG. 1B, it is possible to reduce the contact area of the side wall surface 10w constituting the inner hole of the magnetic-disk glass substrate G and the spindle, and thus suppress rubbing of the magnetic disk against the spindle while securing a desired thickness with which no fluttering occurs when the magnetic disk is rotated at a high rotation rate. It is preferable that the length (t3 in FIG. 1B) of the recessed portion 10h in the side

wall surface 10w constituting the inner hole of the magnetic-disk glass substrate G is 0.1 mm or more in order to effectively suppress rubbing of the magnetic disk against the spindle. Moreover, it is preferable that the length in the thickness direction (t1+t2 in FIG. 1B) of the side wall surface 10w excluding the recessed portion 10h is 0.8 mm or less.

The recessed portion 10h may have an arc shape as shown in FIG. 1B or may have a U shape or a V shape. Moreover, a plurality of recessed portions may be provided. Although the recessed portion 10h does not rub against the spindle and thus may have any shape, it is preferable that the recessed portion 10h has an arc shape because the side wall surface 10w is not likely to chip. In addition, an arc shape is preferable because chipping and the like are not likely to occur when the recessed portion is formed.

[0028] It should be noted that out of the surfaces forming the side wall surface, the two surfaces in contact with the chamfered surfaces preferably have the same length in the thickness direction (t1 and t2 in FIG. 1B). That is, it is preferable that t1 and t2 are the same length in FIG. 1B. When t1 and t2 are the same length, the magnetic disk produced using the magnetic-disk glass substrate G of this embodiment is rotated with a favorable rotation balance at a high rotation rate, and thus it is possible to suppress fluttering when the magnetic disk is rotated at a high rotation rate.

In particular, when the side wall surface 10w including the recessed portion 10h has a length in the thickness direction (L) of 0.3 mm or less, it is preferable that the ratio of the length of the recessed portion 10h (t3) to the above-described length (L) (i.e., t3/L) is set to be 0.5 or less. When the value of t3/L is higher than 0.5, there is a possibility that t1 and t2 becomes too small, which causes chipping.

[0029] It is preferable that the surface of the recessed portion 10h is polished so as to be a mirror surface. By causing the surface of the recessed portion 10h to be a mirror surface, it is possible to prevent particles from attaching to the recessed portion or from being caught on the recessed portion in a step of

manufacturing a magnetic disk by forming a film on a magnetic-disk glass substrate or a step of integrating the magnetic disk in an HDD, and thus it is possible to keep the surface of the recessed portion clean. Therefore, there is no risk that the recessed portion becomes a source of wastes to deteriorate the yield in the steps.

It is preferable that the surface of the recessed portion 10h has an arithmetic average roughness Ra of 0.1 μm or less. It is possible to obtain the surface roughness of the recessed portion 10h by, for example, measuring the side wall surface 10w using a laser microscope with a wavelength bandwidth set to 0.25 μm to 80 μm and analyzing an area of 50 μm square selected from the measured range.

Moreover, it is preferable that the side wall surface 10w including the surface of the recessed portion 10h is chemically strengthened. Although the lengths t1 and t2 are reduced when the magnetic-disk glass substrate G has a small thickness and/or t3, which is the length in the thickness direction of the recessed portion 10h, is large, even in such a case, it is possible to prevent chipping from occurring in side wall surface 10w (in particular, in the portions constituting t1 and t2 in FIG. 1B) by chemically strengthening the side wall surface 10w including the surface of the recessed portion 10h. Chemical strengthening is effective particularly for a thin substrate such as the magnetic-disk glass substrate G having a thickness of 0.635 mm or less.

[0030] [Method for manufacturing magnetic-disk glass substrate]

Hereinafter, a method for manufacturing the magnetic-disk glass substrate of this embodiment will be described for each step. It should be noted that the order of the steps may be changed as appropriate.

[0031] (1) Raw glass plate molding step

In a step of molding a raw glass plate by a float method, for example, first, a sheet of plate glass is obtained by continuously pouring molten glass, for example, having the above-described composition into a bath filled with molten metal such as tin. The molten glass flows in a traveling direction in the bath

where the temperature is strictly controlled, and a sheet of plate glass having a desired thickness and width is ultimately formed. A raw glass plate having a predetermined shape from which a magnetic-disk glass substrate is to be made is cut out from this sheet of plate glass. Since the surface of the molten tin in the bath is flat, the raw glass plate obtained by a float method has a surface that is sufficiently flat.

Moreover, in the step of molding a raw glass plate, a pressing method described in JP 2011-207738A may be used, for example. The pressing method is a method for obtaining a raw glass plate having a flat plate shape by cutting out a glass gob having a certain size from a glass material, dropping the glass gob in the vertical direction, and then sandwiching the glass gob during the drop between a pair of molds moved in the horizontal direction.

It should be noted that the method for manufacturing a raw glass plate is not limited to the above-described methods and a raw glass plate can be manufactured by a known manufacturing method such as a down draw method, redraw method and fusion method.

[0032] (2) Scribing step

Next, a scribing step will be described. After the pressing step, the molded raw glass plate is scribed in the scribing step.

Here, the term "scribe" means that cutting lines (linear scratches) shaped as two concentric circles (an inner concentric circle and an outer concentric circle) are provided on the surface of the molded raw glass plate using a scriber made of super steel alloy or diamond particles in order to form the shaped raw glass plate into a ring having a predetermined size. The raw glass plate on which the two concentric circles have been scribed is partially heated, and thus the portion outside the outer concentric circle and the portion inside the inner concentric circle are removed due to the difference in thermal expansion in the raw glass plate. Thereby, an annular raw glass plate is obtained.

It should be noted that an annular raw glass plate can be obtained by

forming a circular hole in a raw glass plate using a core drill or the like.

[0033] (3) Shaping step

Next, a shaping step will be described. The shaping step includes chamfering processing that forms chamfered surfaces (the chamfered surfaces 11c and 12c in FIG. 1(b) on the inner hole side) at the end portions of the raw glass plate that has been subjected to the scribing step. The chamfering processing is shape processing that chamfers, using a diamond grindstone, the outer circumferential end portion and the inner circumferential end portion of the raw glass plate that has been subjected to the scribing step. The chamfering angle is, for example, 40° to 70° with respect to the main surface, and is typically 45°.

[0034] (4) Recessed portion processing step

A recessed portion processing step is a step of forming the recessed portion 10h in the side wall surface 10w constituting the inner hole of the annular raw glass plate. FIG. 2 shows a method for forming the recessed portion in the side wall surface constituting the inner hole of an annular raw glass plate. In the recessed portion processing step, the side wall surface is processed by inserting a grindstone 20 provided with a projecting portion 20j that projects so as to have a shape corresponding to the shape of the recessed portion 10h into the inner hole of the raw glass plate and then rotating the grindstone 20 around the axis in the thickness direction of the raw glass plate. The processing is performed individually on a single raw glass plate while the raw glass plate is preferably rotated in the direction opposite to the direction in which the grindstone 20 is rotated.

The grindstone 20 is constituted by, for example, an electrodeposition bond, resin bond or metal bond using diamond abrasive grains having a grain size of SD #325 to 800.

It should be noted that the chamfered surfaces and the recessed portion may be simultaneously formed by using a formed grindstone corresponding to a desired shape in the shaping step without separately performing a recessed

portion processing step.

[0035] (5) Grinding step using fixed abrasive grains

In a grinding step using fixed abrasive grains, grinding processing (machining) is performed on the main surfaces of the raw glass plate using a double-side grinding device including a planetary gear mechanism. The fixed abrasive grains have, for example, a grain size of about 10 μm. The double-side grinding device has a pair of upper and lower surface plates (upper surface plate and lower surface plate), and the raw glass plate is held between the upper surface plate and the lower surface plate. The raw glass plate and the surface plates are relatively moved by moving one or both of the upper surface plate and the lower surface plate, so that both main surfaces of the raw glass plate can be ground. It should be noted that a grinding step using free abrasive grains may be performed instead of the step (5).

[0036] (6) End surface polishing step

Next, an end surface polishing step will be described. After the grinding step using fixed abrasive grains, the end surfaces of the raw glass plate are polished in the end surface polishing step.

In the end surface polishing, the inner circumferential end surface and the outer circumferential end surface of the raw glass plate are given a mirror finish by performing brushing. In this case, a slurry containing fine grains of cerium oxide, zirconia or the like as free abrasive grains is used. Moreover, it is possible to simultaneously polish the side wall surface, the chamfered surfaces and the recessed portion. It is preferable to perform polishing so that the arithmetic average roughness Ra of the surface of the recessed portion is 0.1 μm or less in the end surface polishing step. It should be noted that the side wall surface is preferably polished in the same manner. It is possible to obtain the surface roughness of the recessed portion by, for example, measuring the side wall surface using a laser microscope with a wavelength bandwidth set to 0.25 μm to 80 μm and analyzing an area of 50 μm square selected from the measured range. The machining allowance is, for example, φ10 to 30 μm

when the machining allowance is considered as the amount of change in the diameter of the raw glass plate. By polishing the end surfaces, contamination with attached waste and the like, and damage or impairment such as scratches on the end surfaces of the raw glass plate are eliminated, and therefore, it is possible to prevent thermal asperity and the deposition of ions such as sodium and potassium that causes corrosion.

It should be noted that the depth of the recession of the recessed portion is preferably 50 μm or less after the end surface polishing step. When the depth of the recession is greater than 50 μm, there is a possibility that the strength of the substrate at the inner hole (edge portions of the inner hole) is reduced and the substrate becomes easily broken.

Moreover, it is preferable that at the boundary portion between the chamfered surface and the side wall surface, the radius of curvature is within the range of 0.1 to 0.3 mm. When the radius of curvature is smaller than this range, the edge at the boundary portion becomes excessively sharp, and therefore, the edge becomes likely to chip, and to scratch the spindle. Conversely, when the radius of curvature is greater than this range, there is a possibility that the side wall surface is not likely to be a flat surface in the thickness direction, and thus the variation in the inner diameter is not within tolerance.

Furthermore, the recessed portion may be formed by brushing the inner circumferential end surface. Thereby, it is possible to slowly form the recessed portion while performing mirror polishing, and therefore, it is possible to stably produce the glass substrate without generating chipping when forming the recessed portion. It should be noted that in this case, the shape of the recessed portion can be changed by changing various conditions such as the pressure at which the polishing brush is pressed against the end surface of the glass substrate, the specification of the brush, and the rotation rates of the brush and the glass substrate. It is possible to mainly form a recessed portion having an arc shape by brushing.

[0037] (7) First polishing (main surface polishing) step

Next, first polishing is performed on the main surfaces of the raw glass plate that has been subjected to the end surface polishing step.

In the first polishing step, polishing is performed, for example, using a double-side polishing device including a planetary gear mechanism while a polishing liquid is supplied. The first polishing step differs from the grinding using fixed abrasive grains in that free abrasive grains suspended in a slurry are used instead of the fixed abrasive grains. For example, cerium oxide abrasive grains or zirconia abrasive grains suspended in a slurry are used as the free abrasive grains for the first polishing. The double-side polishing device has a pair of upper and lower surface plates (upper surface plate and lower surface plate), and the raw glass plate is held between the upper surface plate and the lower surface plate. It should be noted that planar polishing pads having an annular shape as a whole are attached to the upper surface of the lower surface plate and the bottom surface of the upper surface plate. The raw glass plate and the surface plates are relatively moved by moving one or both of the upper surface plate and the lower surface plate, so that both main surfaces of the raw glass plate can be polished.

[0038] (8) Chemical strengthening step

Next, the raw glass plate that has been subjected to the first polishing step is chemically strengthened.

For example, a mixed solution of potassium nitrate (60 wt%) and sodium sulfate (40 wt%) or the like can be used as a chemical strengthening liquid. In the chemical strengthening step, the chemical strengthening liquid is heated to, for example, 300°C to 400°C, the washed raw glass plate is preheated, and then the raw glass plate is immersed in the chemical strengthening liquid for, for example, 3 to 4 hours. It is preferable that this immersion is performed in a state where the raw glass plates are accommodated in a holder such that a plurality of raw glass plates are held at their end surfaces so that the entirety of the main surfaces of the raw glass

plates are chemically strengthened.

[0039] By immersing the raw glass plate in the chemical strengthening liquid in this manner, lithium ions and sodium ions in the surface layer of the raw glass plate are respectively replaced by sodium ions and potassium ions having a relatively large ion radius in the chemical strengthening liquid, so that a compressive stress layer is formed at the surface layer portion and thus the raw glass plate is strengthened.

[0040] (9) Second polishing (final polishing) step

Next, second polishing is performed on the raw glass plate that has been subjected to the chemical strengthening step. In the second polishing step, for example, the double-side polishing device that has been used in the first polishing is used. In this case, the second polishing step differs from the first polishing step in the type and size of free abrasive grains and the hardness of a resin polisher.

[0041] For example, fine grains of colloidal silica or the like suspended in a slurry are used as the free abrasive grains for the second polishing.

The polished raw glass plate is washed to provide a magnetic-disk glass substrate.

Although it is not necessarily essential to perform the second polishing step, it is preferable to perform the second polishing step because the surface roughness level of the main surfaces of the raw glass plate can be made more favorable. Performing the second polishing step enables the roughness (Ra) of the main surfaces to be 0.15 nm or less. It is possible to use the arithmetic average roughness Ra obtained by measurement with a resolution of 256 by 256 pixels in an area of 1 μm square under an atomic force microscope (AFM) as the roughness (Ra) of the main surfaces.

[0042] [Magnetic disk]

A magnetic disk can be obtained as follows using the magnetic-disk glass substrate.

A magnetic disk has a configuration in which, for example, at least an

attaching layer, a base layer, a magnetic layer (magnetic recording layer), a protecting layer and a lubricant layer are laminated on the main surface of the magnetic-disk glass substrate (hereinafter, referred to as merely "substrate") in this order from the side of the main surface.

For example, the substrate is introduced into a film forming device that has been evacuated and the layers from the attaching layer to the magnetic layer are sequentially formed on the main surface of the substrate in an Ar atmosphere by a DC magnetron sputtering method. For example, CrTi can be used as the attaching layer and CrRu can be used as the base layer. For example, a CoPt-based alloy can be used as the magnetic layer. Also, a CoPt-based alloy or a FePt-based alloy having an L_{10} ordered structure is formed to be the magnetic layer for thermally assisted magnetic recording. After the films are formed as described above, by forming the protecting layer using C_2H_4 by, for example, a CVD method and subsequently performing a nitriding treatment that introduces nitrogen to the surface, a magnetic recording medium can be formed. Thereafter, by coating the protecting layer with perfluoropolyether (PFPE) by a dip coat method, the lubricant layer can be formed.

A manufactured magnetic disk is preferably incorporated in a hard disk drive (HDD) serving as a magnetic recording and reproducing device provided with a magnetic head in which a dynamic flying height (DFH) control mechanism is provided and a spindle for fixing the magnetic disk.

[0043] [Working examples and comparative examples]

In order to confirm the effect of the method for manufacturing a magnetic-disk glass substrate according to this embodiment, 2.5-inch magnetic disks were produced using manufactured glass substrates and an LUL endurance test was performed to check whether troubles such as head crash and thermal asperity occur.

The manufactured magnetic-disk glass substrates are constituted by amorphous aluminosilicate glass having the composition as follows.

[Glass composition]

The manufactured magnetic-disk glass substrates are constituted by amorphous aluminosilicate glass that contains, in terms of oxide amount in mol%, SiO_2 in an amount of 50 to 75%, Al_2O_3 in an amount of 1 to 15%, at least one component selected from Li_2O, Na_2O and K_2O in a total amount of 5 to 35%, at least one component selected from MgO, CaO, SrO, BaO and ZnO in a total amount of 0 to 20%, and at least one component selected from ZrO_2, TiO_2, La_2O_3, Y_2O_3, Ta_2O_5, Nb_2O_5 and HfO_2 in a total amount of 0 to 10%.

[0044] The steps of the method for manufacturing a glass substrate according to this embodiment were performed in the given order.

Here, the pressing method used in the method for manufacturing a magnetic-disk glass substrate described in JP 2011-207738A was used in molding of the raw glass plates in step (1). Table 1 shows the thickness of the obtained raw glass plates. Also, Table 1 shows the length (L in FIG. 1B) in the thickness direction of the side wall surface constituting the inner hole after the shaping processing (chamfering processing) in step (3).

In the shaping processing in step (3), the chamfering angle was set to 45°.

In the recessed portion processing in step (4), the recessed portion was formed with an electrodeposition bond grindstone using diamond abrasive grains having a grain size of SD #325 to 800. Table 1 shows the length in the thickness direction (t1+t2) of the side wall surface constituting the inner hole excluding the recessed portion in working examples. The recessed portion had a cross section in the thickness direction having an arc shape, had a depth of 20 μm from the side wall surface at the deepest point, and was formed over the entire circumference in the circumferential direction.

In the grinding using fixing abrasive grains in step (5), grinding was performed using a grinding device in which diamond sheets were attached to the upper and lower surface plates.

In the end surface polishing in step (6), a plurality of raw glass plates

stacked with spacers being arranged between the raw glass plates were polished with a polishing brush using cerium oxide having an average grain diameter (D50) of 1.0 μm as free abrasive grains.

In the first polishing in step (7), polishing was performed for 60 minutes using a double-side polishing device including a planetary gear mechanism with a slurry containing cerium oxide abrasive grains.

In the chemical strengthening in step (8), a mixed solution of potassium nitrate (60 wt%) and sodium sulfate (40 wt%) or the like was used as a chemical strengthening liquid, the temperature of the chemical strengthening liquid was set to 350°C, and the raw glass plate preheated in advance was immersed in the chemical strengthening liquid for four hours.

In the second polishing in step (9), polishing was performed for 30 minutes using the same double-side polishing device as in the first polishing with a slurry in which fine grains of colloidal silica were suspended. The raw glass plate that had been subjected to the second polishing was washed using a neutral cleaning liquid and an alkaline cleaning liquid. Thereby, a magnetic-disk glass substrate was obtained. The compressive stress layer obtained by the chemical strengthening was formed on the recessed portion as well by the above-described steps. Moreover, the measured roughness of the recessed portion in each working example and the comparative example was 0.1 μm or less in Ra.

[0045]Table 1

	Thickness (mm)	L (mm)	Recessed portion	t1+t2 (mm)	t3 (mm)	LUL endurance test
Com. Ex. 1	1.27	0.97	No	0.97	0	Fail
Work. Ex. 1	1.27	0.97	Yes	0.37	0.6	Pass
Work. Ex. 2	1.27	0.97	Yes	0.77	0.2	Pass
Work. Ex. 3	1.27	0.97	Yes	0.87	0.1	Pass
Work. Ex. 4	1.0	0.7	Yes	0.5	0.2	Pass
Work.	0.8	0.5	Yes	0.3	0.2	Pass

Ex. 5						
Work. Ex. 6	0.635	0.335	Yes	0.135	0.2	Pass
Work. Ex. 7	0.635	0.335	Yes	0.235	0.1	Pass

[0046] Magnetic disks having a magnetic layer formed on the obtained magnetic-disk glass substrates were produced. Then, each magnetic disk was removed from and reattached to the spindle of a hard disk drive (HDD) having a rotation rate of 10000 rpm ten times, and then the magnetic disks were incorporated in the HDD and evaluated by performing an LUL endurance test (600000 times). The LUL endurance test is a test in which the head is moved back and forth (seek operation) between the ramp and an ID stopper without stopping the motion in a state where the hard disk drive (HDD) provided with the magnetic disk is placed in a constant temperature and humidity chamber with a temperature of 70°C and a humidity of 80%, and abnormalities such as dirt and abrasion of the head are checked after the test. After the LUL test was performed 80,000 times/day × 7.5 days = 600,000 times, the head ABS surface was magnified with a microscope and was visually observed. If the attachment of a contaminant, abrasion or chipping was observed, the magnetic disk did not pass the test.

[0047] Working Examples 1 to 7 passed the LUL endurance test, but Comparative Example 1 did not pass the test because the attachment of a contaminant on the magnetic head was observed. When the composition of this contaminant was analyzed, a metal composition thought to be the material of the spindle or the film of the magnetic disk was detected. That is, it was found that the reason why Comparative Example 1 did not pass the above-described endurance test was that impurities were generated by rubbing between the magnetic disk and the spindle when the magnetic disk was removed from and reattached to the spindle, and the impurities moved and attached to the main surfaces of the magnetic disk. Therefore, it is understood that when the contact area of the side wall surface of the magnetic disk and the

spindle is reduced to make it unlikely for the two to rub against each other, troubles such as head crash and thermal asperity are not likely to occur. By providing the recessed portion in the side wall portion and thus reducing the contact area of the side wall surface and the spindle, relatively thick magnetic disks such as in Examples 1 to 3 could also pass the above-described LUL endurance test.

It should be noted that a certification test (magnetic signals writing/reading test) was performed on the HDD prior to the LUL endurance test, and no abnormalities were particularly found in Working Examples 1 to 7 and Comparative Example 1. That is, no errors occurred due to fluttering.

[0048] When the rotation rate of the magnetic disk is further increased from 10000 rpm, for example, when the magnetic disk is used in a server device premised on a high rotation rate of 15000 rpm or more, there is a possibility that errors occur due to fluttering in the certification test because a relatively thin magnetic disk tends not to have enough rigidity.

Therefore, it is preferable that the thickness of the magnetic disk is 1.0 mm or more in order to both suppress fluttering when the magnetic disk is rotated at a high rotation rate and reduce the contact area of the side wall surface and the spindle by providing the recessed portion in the side wall portion.

[0049] Next, a magnetic-disk glass substrate (Reference Example 1) in which the thickness was 0.5 mm, L was 0.3 mm, the recessed portion was present, t1+t2 was 0.15 mm, and t3 was 0.15 mm was produced in the same manner as the working examples shown in Table 1. Furthermore, when a magnetic disk having a magnetic layer formed on the obtained magnetic-disk glass substrate was produced and the LUL endurance test was performed in the same manner as in the working examples, the magnetic disk passed the test. Moreover, when the side wall surface of the inner hole was observed after the LUL endurance test, no chipping was found.

On the other hand, a magnetic-disk glass substrate (Reference Example

2) was produced in the same manner as Reference Example 1, except that t1+t2 was 0.10 mm and t3 was 0.20 mm, and the LUL endurance test was performed in the same manner. In this case, although the magnetic disk passed the test, when the side wall surface of the inner hole was observed after the test, chipping was found at one portion.

That is, it was confirmed that even when a magnetic disk is thin, for example, L is 0.3 mm or less, chipping is not likely to occur by causing the length of the portion that is in contact with the spindle to make up greater than or equal to a certain ratio of the length in the thickness direction of the side wall surface (specifically, the value of t3/L is 0.5 or less).

It should be noted that a certification test was performed on the HDDs prior to the LUL endurance test, and no abnormalities were particularly found in the produced magnetic disk. That is, no errors occurred due to fluttering.

[0050] While a method for manufacturing a magnetic-disk glass substrate according to the present invention has been described in detail, the present invention is not limited to the above-described embodiment, and it will be appreciated that various improvements and modifications can be made without departing from the spirit of the present invention.

CLAIMS

1. A magnetic-disk glass substrate having a doughnut shape comprising:

a pair of main surfaces;

two side wall surfaces constituting an inner hole and a contour; and

chamfered surfaces between the main surfaces and the side wall surfaces,

wherein the side wall surface constituting the inner hole has a recessed portion.

2. The magnetic-disk glass substrate according to claim 1,

wherein the side wall surface constituting the inner hole includes a surface orthogonal to the main surfaces.

3. The magnetic-disk glass substrate according to claim 1 or 2, which has a thickness of 1.0 mm or more.

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

wherein the side wall surface that constitutes the inner hole and includes the recessed portion has a length in a thickness direction of 0.7 mm or more.

5. The magnetic-disk glass substrate according to any one of claims 1 to 4,

wherein the side wall surface constituting the inner hole has a length in a thickness direction excluding the recessed portion of 0.8 mm or less.

6. The magnetic-disk glass substrate according to any one of claims 1 to 5,

wherein the surface of the recessed portion is polished so as to be a mirror surface.

7. The magnetic-disk glass substrate according to any one of claims 1 to 6, wherein a recession of the recessed portion has a maximum depth of 50 μm or less.

8. The magnetic-disk glass substrate according to any one of claims 1 to 7, wherein the recessed portion is formed over the entire circumference of the side wall surface.

9. A magnetic disk having at least a magnetic layer formed on the magnetic-disk glass substrate according to any one of claims 1 to 8.

10. A magnetic-disk drive device comprising:
the magnetic disk according to claim 9;
a spindle for fixing the magnetic disk; and
a magnetic head.