

MANUFACTURING METHOD OF GLASS SUBSTRATE FOR MAGNETIC DISK

FIELD

[0001]

The present invention relates to a glass substrate for magnetic disk having a pair of principal surfaces and a manufacturing method thereof.

BACKGROUND

[0002]

Recently, a hard disk device is incorporated in a personal computer, a notebook personal computer, and a DVD (Digital Versatile Disc) recording apparatus in order to record data. Particularly, in the hard disk device applied in an apparatus such as the notebook personal computer for portable use, a magnetic disk in which a magnetic layer is provided on a glass substrate is used, and magnetic recording information is recorded in or read from a magnetic layer using a magnetic head (DFH (Dynamic Flying Height) head) that is slightly floated on a surface of the magnetic disk surface. A glass substrate is suitably used as the substrate for the magnetic disk because substrate is hardly plastically deformed in comparison with a metallic substrate.

[0003]

The magnetic recording density is being increased because of the demand for an increased storage capacity in the hard disk device. For example, a magnetic recording information area is finely formed using a perpendicular magnetic recording system in which a magnetization direction of the magnetic layer is oriented toward a direction perpendicular to the substrate surface, which allows the storage capacity to be increased in a single disk substrate. In order to further increase the storage capacity, a floating distance of the magnetic head from the magnetic recording surface is extremely shortened to obtain the fine magnetic recording information area (namely to obtain an increased S/N (Signal to Noise) ratio). In the substrate of the magnetic disk, the magnetic layer is formed flat such that the magnetization direction of the magnetic layer is oriented toward the direction substantially perpendicular to the substrate surface. Therefore, the glass substrate is formed such that surface irregularity of the glass substrate is decreased as much as possible.

[0004]

A manufacturing method of glass substrate for magnetic disk includes, for example, a machining process (coring process) for forming a sheet glass material annularly; a chamfering process for chamfering inner end face and outer end face of an annular sheet glass material; and

an edge-polishing process for mirror finishing the inner end face and the outer end face.

The coring process has been performed one by one conventionally, while a process is known which drills through a plurality of sheet glass materials to produce a plurality of annular sheet glass material at one time, thereby shortening tact time of manufacturing (for example, see Japanese Laid-open Patent Publication No. 2007-283651). Japanese Laid-open Patent Publication No. 2007-283651 discloses machining (cutting) a laminate of a plurality of sheet glass materials cylindrically by revolving and moving a coring machine in the direction of lamination, in order to form an inner surface and an outer surface of the laminate.

SUMMARY OF THE INVENTION

[0005]

Recently, improvement for uniformity of an inner hole of a glass substrate for magnetic disk has been requested because of the following reason.

As described above, a magnetic recording information area is finely formed using a perpendicular magnetic recording system. With that system, area for one bit recording (magnetic domain) is extremely narrow, and a plurality of tracks (recording area), each of which is concentrically formed from the inner hole toward the outer edge, is also extremely narrow. Thus, TMR (Track Miss-Read) can arise between adjoining tracks when a play between an inner hole of a magnetic disk and a spindle of a hard disk device is large after the magnetic disk is assembled into the device. Therefore, uniformity of the inner hole of the glass substrate for magnetic disk has been requested to achieve a value of 2 μm or less, for example.

[0006]

On the other hand, in order to achieve a value of 2 μm or less for example, as uniformity of the inner hole of the glass substrate for magnetic disk, it is required to perform coring process (machining process) with high accuracy because of the following reason.

When uniformity of an inner hole formed in the coring process is not at acceptable level, stock removal should be accordingly large in the later chamfering process by applying a machining blade with coarser abrasive for example. However, when applying a machining blade with coarser abrasive, inner edge is likely to crack. In this regard, in order for the inner edge not to crack by making stock removal small in the chamfering process, it is required to perform the preceding coring process (machining process) with high accuracy. Note that, in the chamfering process, there is conventionally known a method of adjusting the sizes of inner / outer diameters and forming the chamfer surface by end portion forming using form grinding (form blade), that is, by simultaneously machining the end face and the chamfer surface.

[0007]

In another aspect, it has been turned out that a magnetic disk is likely to destroy from the inner end when dropping down an apparatus in which a hard disk device is assembled. Thus, a magnetic disk should have a certain level of strength such that a crack of the inner end does not occur.

Further, reduction of occurrence of the crack in a glass substrate for magnetic disk is requested not only because a certain level of strength needs to be obtained in a drop test for a hard disk device, but also because of the following technique to realize even higher density of the magnetic recording in a magnetic disk.

[0008]

That is, recently, for the purpose of realizing even higher density of the magnetic recording in a magnetic disk, magnetic material whose magnetic anisotropy energy is high such as Fe-Pt, Co-Pt or the like has been studied for use. It is required to make magnetic particles as small as possible to realize high density of the magnetic recording; however, extremely small magnetic particles can lead to a problem of degradation of magnetic property due to heat fluctuation. As is unlikely to be influenced by heat fluctuation, high Ku magnetic material is expected to contribute to high density of the magnetic recording.

On the other hand, high Ku magnetic material needs to have a specific crystal orientation to achieve high Ku, and therefore needs to be processed with high-temperature film formation or high-temperature heat treatment after film formation. In order to manufacture magnetic recording layers of high Ku magnetic material, a glass substrate is requested to have heat resistance property to endure the above high-temperature heat treatment, namely high glass-transition temperature (T_g) such as 600 to 700°C. Here, when a crack occurs at an end face of the glass substrate, the crack can progress during the above high-temperature heat treatment, thereby failing to obtain target strength. In this regard, elimination of occurrence of the crack in a glass substrate for magnetic disk is further requested in order to realize higher density of the magnetic recording in a magnetic disk which utilizes high Ku magnetic material.

[0009]

As described above, it is required to perform the coring process (machining process) with high accuracy in order to avoid occurrence of crack for a glass substrate for magnetic disk. Here, machining fluid (coolant) may not be provided evenly to the outer machining surface with the machining device disclosed in the aforementioned Japanese Laid-open Patent Publication No. 2007-283651. Thus, resistance in machining and a degree of the discharge of glass sludge may be uneven over the entire circumference of the outer machining surface of the laminate, and a degree of machining may be accordingly uneven. As a result, uniformity of the outer machining surface of the laminate may be worse.

[0010]

In the following description, “outer machining surface of laminate” means the outer cylindrical surface of the laminate which is being machined or already machined, or the outer end face of each sheet glass material of the laminate, while “inner machining surface of laminate” means the inner cylindrical surface of the laminate which is being machined or already machined, or the inner end face of each sheet glass material of the laminate.

In the following description, “outer machining surface of coring machine” means the outer surface of the coring machine, that is, the outer surface of the cylindrical outer diameter blade of the coring machine. If thickness of the outer diameter blade of the coring machine were zero, the outer machining surface of laminate would be identical to the outer machining surface of coring machine; however, actually, the outer machining surface of coring machine is positioned more outward than the inner machining surface of laminate by the thickness (1 to 10 mm, for example) of the outer diameter blade of the coring machine.

In the following description, when it is referred uniformity of the outer machining surface or concentricity of the outer machining surface and the inner machining surface, it is understood that the outer machining surface of a laminate or each sheet glass material is referred.

[0011]

Conventionally, when revolving integrated coring cutter with an inner diameter blade and an outer diameter blade concentrically arranged and moving the same in the direction of lamination of the laminate of sheet glass materials, provision (supply) of machining fluid to a machining portion (top of the coring cutter) is likely to be getting short as the coring cutter moves down in the direction of lamination of the laminate, and machining accuracy is likely to be worse. One reason of this is because a distance becomes farther between a position where machining fluid is provided and a position where machining is performed, as the coring cutter moves down. Another reason is because path for machining fluid provided (region between a blade of the coring cutter and the outer machining surface of the laminate) is narrow. That is, the farther the above distance is, the worse uniformity of the sheet glass material is likely to be.

[0012]

When uniformity of the outer machining surface of the laminate is not satisfactory after machining in the coring process, it is difficult to improve afterwards concentricity of the outer machining surface and the inner machining surface. When uniformity of the outer machining surface is not satisfactory, removal stock for a glass substrate may have to be larger in the later chamfering process in order to improve uniformity of the outer machining surface while increasing accuracy of concentricity of the outer machining surface and the inner machining surface. However, when removal stock for a glass substrate is made large in the chamfering

process, the inner end face of the glass substrate is more likely to crack. This is the reason why high accuracy of machining is demanded in the coring process (machining process) such that the stock removal is made smaller in the chamfering process to avoid occurrence of crack. Further, as high-speed rotation of magnetic disk is recently applied in a hard disk device, there may be a problem of fluttering of the magnetic disk when uniformity of the outer machining surface is not satisfactory.

[0013]

In view of the above, an object of the present invention is to provide a manufacturing method of glass substrates for magnetic disks, based on a laminate that is formed with a plurality of sheet glass materials laminated, the method enabling to achieve a desired level of uniformity of the outer machining surface of the laminate, and to achieve therefore a desired level of uniformity of the outer machining surface of each sheet glass material.

[0014]

According to a first embodiment of the present invention, there is provided a manufacturing method of glass substrate for magnetic disk, the method comprising the steps of preparing a laminate that is formed with a plurality of sheet glass materials laminated, and machining the laminate by revolving and moving a coring machine in the direction of lamination, the coring machine concentrically having an outer diameter blade of large diameter and an inner diameter blade of small diameter, while providing outer and inner machining surfaces with machining fluid, the outer and inner machining surfaces contacting the sheet glass materials, wherein a direction of the revolution of the coring machine and a flow direction of the machining fluid are arranged such that the machining fluid is well drawn into the outer machining surface.

[0015]

In the above manufacturing method, preferably, the machining fluid is provided with a nozzle, and the flow direction of the machining fluid is a direction of a vector directing from the nozzle to a point on the outer machining surface, such that, from a plan view, an angle ranges from 0 to 15 degrees which is formed by a line connecting the nozzle and said point and a tangential line at said point, and wherein said direction is substantially consistent with a revolving direction of the coring machine, and said vector has a downward component.

[0016]

In the above manufacturing method, preferably, the machining fluid is provided with a nozzle, and the flow direction of the machining fluid is a direction of a vector directing from the nozzle to a point on the outer machining surface from a plan view, and wherein said direction is substantially consistent with a revolving direction of the coring machine, and said vector has a downward component.

[0017]

Preferably, the machining fluid is provided to the outer machining surface by use of a plurality of nozzles, the nozzles being positioned substantially evenly over the entire circumference of the outer diameter blade in said machining.

[0018]

Preferably, the machining fluid is provided to the outer machining surface by use of single or a plurality of nozzles, the nozzle or nozzles positioned toward the outer diameter blade and revolved concentrically with the outer diameter blade.

[0019]

In the above manufacturing method, uniformity of the outer circumference of the glass substrate for magnetic disk is 5 μm or less.

[0020]

According to a second embodiment of the present invention, there is provided a manufacturing method of glass substrate for magnetic disk, the method comprising the steps of: preparing a laminate that is formed with a plurality of sheet glass materials laminated; immersing the laminate in machining fluid; and machining the laminate by revolving and moving a coring machine in the direction of lamination, the coring machine concentrically having an outer diameter blade of large diameter and an inner diameter blade of small diameter.

[0021]

According to a second embodiment of the present invention, there is also provided a manufacturing method of glass substrate for magnetic disk, the method comprising the steps of: preparing a laminate that is formed with a plurality of sheet glass materials laminated; immersing the laminate in machining fluid; and machining the laminate by revolving and moving a coring machine in the direction of lamination, the coring machine concentrically having an outer diameter blade of large diameter and an inner diameter blade of small diameter, while providing inner machining surface with machining fluid, the inner machining surface contacting the sheet glass materials.

[0022]

The above manufacturing method preferably further includes circulating the machining fluid in which the laminate is immersed.

[0023]

In the above manufacturing method, the abrasive grit size of the inner diameter blade is preferably greater than that of the outer diameter blade.

[0024]

In the above manufacturing method, preferably, the abrasive grit size of the inner

diameter blade ranges from 150 to 800 while the abrasive grit size of the outer diameter blade ranges from 120 to 600.

[0025]

The above manufacturing method preferably further includes edge-polishing for polishing end faces of the sheet glass material.

[0026]

The object and advantages of the invention will be realized and attained by means of the elements and combinations particularly pointed out in the claims.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are not restrictive of the invention, as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027]

Referring now to the attached drawings which form a part of this original disclosure:

FIG. 1 is a view illustrating an example of a section of a laminate that is formed with a plurality of sheet glass materials and bonding agents laminated according to an embodiment of the invention;

FIG. 2 is a view illustrating a machining system for machining a plurality of sheet glass materials in a coring process according to an embodiment of the invention;

FIG. 3 is a view illustrating an integrated coring machine (drill) used in a coring process according to an embodiment of the invention;

FIG. 4 is a view illustrating flow directions of coolant on a plane orthogonal to a direction of lamination of the sheet glass materials;

FIG. 5 is a view illustrating a target position for coolant provision from the plan view.

FIG. 6 is a view illustrating a modified machining system for machining a plurality of sheet glass materials in a coring process according to an embodiment of the invention;

FIG. 7 is a view illustrating a laminate immersion process according to the second embodiment of the invention; and

FIG. 8 is a view illustrating a machining system for machining a plurality of sheet glass materials in a coring process according to the second embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0028]

In the following explanation, it is appreciated by the skilled in the art that abrasive grit

size refers to the size of the grains of machining materials embedded in a machining blade. As abrasive grit size applied is greater, average grain diameter becomes smaller (that is, average grain becomes finer.).

[0029]

- Glass Substrate for Magnetic Disk

Glass material for a glass substrate for magnetic disk according to the embodiments of the present invention may be aluminosilicate glass, soda-lime glass, borosilicate glass or the like. Particularly, the aluminosilicate glass can be suitably used in that chemically strengthening can be performed, and in that the glass substrate for magnetic disk is obtained which is excellent for the flatness of the principal surface and its strength.

[0030]

Composition of the glass substrate may be preferably, but not limited to, the following. That is, for example, principal composition of the glass substrate according to the present embodiments may include 58 to 75% SiO_2 , 5 to 23% Al_2O_3 , 3 to 10% Li_2O , and 4 to 13% Na_2O by weight percent.

[0031]

The glass substrate according to the present embodiments may be more preferably aluminosilicate glass that includes, as principal composition, 62 to 75% SiO_2 , 5 to 15% Al_2O_3 , 4 to 10% Li_2O , 4 to 12% Na_2O , 5.5 to 15% ZrO_2 by weight percent where the weight ratios of $\text{Na}_2\text{O} / \text{ZrO}_2$ and $\text{Al}_2\text{O}_3 / \text{ZrO}_2$ are 0.5 to 2.0 and 0.4 to 2.5 respectively.

[0032]

Alternatively, the glass substrate according to the present embodiments may be preferably aluminosilicate glass that includes 61 to 70% SiO_2 , 9 to 18% Al_2O_3 , 2 to 3.9% Li_2O , 6 to 13% Na_2O , 0 to 5% K_2O , 10 to 16% R_2O ($\text{R}_2\text{O} = \text{Li}_2\text{O} + \text{Na}_2\text{O} + \text{K}_2\text{O}$), 0 to 3.5% MgO , 1 to 7% CaO , 0 to 2 % SrO , 0 to 2% BaO , 2 to 10% RO ($\text{RO} = \text{MgO} + \text{CaO} + \text{SrO} + \text{BaO}$), 0 to 2% TiO_2 , 0 to 2% CeO_2 , 0 to 2% Fe_2O_3 , 0 to 1% MnO by weight percent where total weigh percent of TiO_2 , CeO_2 , Fe_2O_3 and MnO ranges from 0.01 to 3%.

[0033]

The glass substrate according to the present embodiments may be relatively thin and annular. Size of the glass substrate according to the present embodiments may be preferably, but not limited to, nominal 2.5 inches in diameter or even smaller (1 inch for example).

[0034]

A manufacturing method of glass substrate for magnetic disk and a glass substrate for magnetic disk according to embodiments of the present invention will be described in detail below.

- A Manufacturing Method of Glass Substrate for Magnetic Disk according to the First Embodiment

A manufacturing method of glass substrate for magnetic disk according to the first embodiment will be explained hereinafter for each process. Note that order of each process may be exchanged.

[0035]

(1) Forming Process of Sheet Glass Material and Lapping Process

Float method may be preferably applied for the forming process. With the float method, sheet glass is obtained by continuously running molten glass of the above described composition for example into a bath filled with molten metal such as tin. The molten glass is flowed along a predetermined direction in the bath under strict temperature control to finally obtain sheet glass material of desired thickness and width. The obtained sheet glass material is cut to produce sheet glass materials, each of which has a predetermined shape for a basis of a glass substrate for magnetic disk. Because a surface of the molten metal (molten tin for example) in the bath is flat, flatness of the sheet glass materials obtained with the float method becomes excellent. Thickness of the sheet glass materials obtained with the float method may be 0.6 to 1.4 mm, and surface roughness Ra (arithmetic mean value of roughness) of the sheet glass materials may be 0.01 μm or less.

Note that the sheet glass material according to the embodiment may be manufactured not only with the float method described above but also with the other known method such as press forming, down-draw method, redraw method, or fusion method.

[0036]

Next, a lapping process is applied as necessary for both principal surfaces of the sheet glass material of the predetermined size by use of loose abrasives of alumina system. More specifically, the lapping is performed by pressing surface plates on both principal surfaces of the sheet glass material and relatively moving the surface plates and the principal surfaces of the sheet glass while providing machining fluid (slurry) including loose abrasives with the principal surfaces of the sheet glass material. Note that when the sheet glass material is formed with the float method described above, surface roughness level becomes excellent and the lapping process may be therefore omitted.

[0037]

(2) Laminate Preparation Process

The cut sheet glass material during the process described above has a rectangular (square for example) of a predetermined size that is a little larger than a targeted glass substrate for magnetic disk. For example, a sheet glass material is cut to produce a sheet glass material

of size of 75 mm x 75 mm in order to manufacture a glass substrate for magnetic disk of 2.5 inches.

[0038]

In the laminate preparation process, a laminate formed with a plurality of sheet glass materials is prepared by sequentially coating or pasting a bonding agent and/or a spacer between two adjacent sheet glass materials. This laminate is prepared such that a plurality of sheet glass materials are machined integrally in the later described coring process. Note that the chamfering process and/or the edge-polishing process after the coring process may be performed integrally for the laminate.

[0039]

Referring now to Fig. 1, arrangement of the laminate according to the present embodiment will be described. Fig. 1 is a view illustrating an example of a section of a laminate according to the present embodiment. As illustrated in Fig. 1, a laminate 5 according to the present embodiment is comprised of a plurality of sheet glass materials 5a and bonding agents 5b laminated in an alternating sequence. The laminate 5 is produced by coating or pasting the bonding agent 5b between the two adjacent sheet glass materials 5a.

[0040]

Any material may be applied for the bonding agent 5b, as long as it is able to attach and detach two adjacent sheet glass materials. For example, UV (ultraviolet) - cured resin is preferable for the bonding agent 5b in that bonding workability is satisfactory, as UV-cured resin is easily solidified with irradiation of UV rays of predetermined wavelength. Further, UV-cured resin may be preferably chosen such that the sheet glass materials can be easily separated with hot water or organic solvent. Bonding agents other than UV-cured resin such as wax, photo-curing resin, or visible light curing resin may be used. Wax is advantageous in that it can be liquefied at a predetermined temperature while solidified at room temperature and attachment / detachment workability is therefore satisfactory.

When pasting spacers instead of bonding agents, thin spacers made of resin, fiber, rubber, metal, or ceramic may be used. Thickness of the bonding agent and spacer may be, for example, 0.01 to 2 mm.

[0041]

(3) Coring Process (Machining Process)

A coring process is a process for machining the laminate 5 formed with a plurality of sheet glass materials by use of an integrated coring machine (drill) to produce an annular laminate of sheet glass materials with an inner hole formed. Referring now to Figs. 2 and 3, the coring process (machining process) will be explained. FIG. 2 is a view illustrating a machining

system for machining a plurality of sheet glass materials in a coring process according to the present embodiment. FIG. 3 is a view illustrating a section of an integrated coring machine used in the coring process according to present embodiment.

[0042]

As illustrated in Fig. 2, the machining system according to the present embodiment includes a main device 10, a shaft 12, a coolant providing hoses 15 (15a, 15b), and an integrated coring machine 20. The main device 10 drives the integrated coring machine 20. The main device 10 provides inside of the integrated coring machine 20 with coolant through a coolant providing tube 17.

The integrated coring machine 20 has substantially a cylindrical shape as a whole. The integrated coring machine 20 is supported by the shaft 12 made of stainless material with high stiffness for example. The cylindrical shaft 12 is support by the main device 10 while revolving on its own axis. The shaft 12 is driven by a spindle motor (now shown) in the main device 10 with its revolution controlled at a desired level.

[0043]

The shaft 12 and the integrated coring machine 20 is concentrically positioned, and with the revolution of the shaft 12 on its own axis, the integrated coring machine 20 is therefore able to revolve at a high revolution substantially without fluctuation of its center. Thus, it is possible to machine with high accuracy the annular laminate 5 of sheet glass materials with the inner hole formed. It is also possible to avoid a damage of the glass surface of the laminate 5 in an initial stage of machining in which the integrated coring machine 20 begins to contact the glass surface (top surface) of the laminate 5.

[0044]

As illustrated in Fig. 2, the integrated coring machine 20 is positioned above the laminate 5 placed on a mounting stand 30. Note that, although now shown, the mounting stand 30 may be preferably equipped with a stopper such that the laminate 5 does not move laterally on a mounting surface of the mounting stand 30 during the machining.

The machining system according to the present embodiment is able to move up and down with a servo mechanism (not shown), which allows the integrated coring machine 20, the shaft 12 and the coolant providing hoses 15 to integrally move up and down.

[0045]

Here, as illustrated in Fig. 3, the integrated coring machine 20 is concentrically equipped with an outer diameter blade 20a of large diameter and an inner diameter blade 20b of small diameter.

Further, as illustrated in Fig. 2, a hollow 30a for receiving the outer diameter blade 20a

and a hollow 30b for receiving the inner diameter blade 20b are formed in the mounting stand 30. The hollows 30a, 30b are respectively formed to prevent the blade 20a, 20b of the integrated coring machine 20 from colliding with the mounting surface of the mounting stand 30.

[0046]

As illustrated in Fig. 2, the shaft 12 is equipped inside with the coolant providing tube 17. A nozzle 17a, which is positioned at the top of the coolant providing tube 17, provides inner machining surface of the coring machine with machining fluid. The inner machining surface of the coring machine is a surface of the inner diameter blade 20b that contacts the laminate 5.

[0047]

In this embodiment, the main device 10 is equipped with the plurality of coolant providing hoses 15. In the example illustrated in Fig. 2, the main device 10 is equipped with two coolant providing hoses 15a, 15b; however, number of the coolant providing hoses 15 is not limited to two. Three or more coolant providing hoses 15 may be even more preferably equipped along the circumference of the integrated coring machine 20.

Note that it is preferable to position the plurality of coolant providing hoses 15 substantially evenly over the entire circumference of the outer diameter blade 20a.

[0048]

Each of the coolant providing hoses 15 may be a flexible hose. A flow direction of coolant from a nozzle 16 at the top of each of the coolant providing hoses 15 is arranged such that coolant is well drawn into the outer machining surface of the integrated coring machine 20.

Coolant is preferably provided as jet having a certain diameter, flow rate, and flow direction. This allows a control of position where coolant is provided (that is, position where coolant is hit), and allows a control of relative speed of the coolant being hit with regard to the outer diameter blade and/or the laminate, when the coring machine moves.

[0049]

Here, with reference to Figs. 2 and 4, a flow direction of coolant toward the outer machining surface of the integrated coring machine 20 will be explained. Fig. 4 is a view illustrating flow directions of coolant on a plane orthogonal to the direction of lamination of the laminate 5 (that is, from a plan view).

As illustrated in Fig. 4, the flow direction of coolant provided is preferably a direction of a tangent vector (lateral component) tangential to the cylindrical outer machining surface 32 of the integrated coring machine 20 from the nozzle 16 (16a, 16b) on a plane orthogonal to the direction of lamination of the laminate 5. The direction of the tangent vector is substantially consistent with the direction of revolution of the integrated coring machine 20. That is, each of

two vectors V_a and V_a' are assumed as a tangent vector tangential to the cylindrical outer machining surface 32 from the nozzle 16 (16a, 16b); however, the flow direction of coolant provided from the nozzle 16a is limited to a direction of vector V_a , which is substantially consistent with the revolving direction of the coring machine. In the similar fashion, the flow direction of coolant provided from the nozzle 16b is a direction of vector V_b .

[0050]

Further, as illustrated in Fig. 2, the flow direction of coolant is a direction of vector that includes a component vector V_z , the direction of which is substantially consistent with the moving direction of the integrated coring machine 20 (namely, downward direction in Fig. 2). The same applies to the nozzle 16b.

That is, a flow direction from the nozzle 16a is a direction of a vector that is obtained to combine the vector V_a (lateral component) with and the vector V_z (downward component), while a flow direction from the nozzle 16b is a direction of a vector that is obtained to combine the vector V_b (lateral component) with and the vector V_z (downward component).

[0051]

Note that a tank that reserves coolant provided to the outer machining surface and the inner machining surface, a pump and tubes/hoses that introduce coolant from the tank to the coolant providing hoses 15 and 17 are prepared; however, they are omitted in the illustrated machining system for the sake of brevity.

In the above explanation, provision direction of coolant from the nozzle 16 is, from the plan view, the direction of the tangent vector tangential to the outer machining surface 32 of the integrated coring machine 20; however, provision direction of coolant from the nozzle 16 may be a direction of a tangent vector tangential to the outer machining surface of the laminate, because the thickness of the outer machining blade 20a of the integrated coring machine 20 is relatively small in comparison with the diameter of the laminate.

[0052]

In the coring process according to the present embodiment, machining for the laminate 5 is performed as follows by use of the machining system illustrated in Fig. 2.

First, as illustrated in Fig. 2, the integrated coring machine 20 is located above the laminate 5 placed on a mounting stand 30. Next, the shaft 12 is revolved while the main device 10 is moved down. The revolution of the shaft 12 is around 1,500 to 15,000 rpm. As a result, the integrated coring machine 20 is revolved around the center axis of the shaft 12, while moved in the direction of lamination of the laminate 5 (that is, downward direction).

[0053]

The integrated coring machine 20 is moved down until it reaches to the hollows 30a,

30b of the mounting stand 30. During the machining for the laminate 5 by use of the integrated coring machine 20, coolant is provided from the nozzle 16 of the coolant providing hoses 15 (15a, 15b) and the nozzle 17a of the coolant providing hoses 17.

[0054]

In order for coolant to be sufficiently soaked into the outer machining surface and the inner machining surface during the machining for the laminate 5 by use of the integrated coring machine 20, the machining process may be preferably performed in the following way. That is, the integrated coring machine 20 is moved up every time the integrated coring machine 20 descends by a certain amount in order to effectively introduce or draw coolant into the machining surfaces (particularly, inner machining surface). After moved up, the integrated coring machine 20 is again moved down to proceed machining. Further, in order to improve machining efficiency, the integrated coring machine 20 may be preferably vibrated minutely in the upward and downward direction with an ultrasonic generator (not shown) during the machining for the laminate 5. For example, frequency of the ultrasonic vibration may be 20 kHz, while amplitude of the ultrasonic vibration may be around 5 to 7 μm .

[0055]

Here, the outer diameter blade 20a and the inner diameter blade 20b of the integrated coring machine 20 according to the present embodiment will be further explained below.

The outer diameter blade 20a and the inner diameter blade 20b of the integrated coring machine 20 are, but not limited to, metal-bond blades that includes abrasive grains of diamond and grain binder of bronze or cast iron for example. The blades 20a, 20b may be resin-bond blades including resin-based grain binders, vitrified-bond blades including glassy ceramics-based binders, or electrocoat-bond blades utilizing electroplating. Thickness of the top of the outer diameter blade 20a and the inner diameter blade 20b is around 1 to 10 mm.

[0056]

It is preferable that the abrasive grit size of the inner diameter blade 20b is substantially the same as or greater than that of the outer diameter blade 20a. It is even more preferable that the abrasive grit size of the inner diameter blade 20b is greater than that of the outer diameter blade 20a. That is, the abrasive grains of the inner diameter blade 20b are substantially the same as or finer than that of the outer diameter blade 20a.

A range of the abrasive grit size of the inner diameter blade 20b is determined as follows; that is, the lower limit of the range is determined based on requirements for uniformity of the glass substrate for magnetic disk, while the upper limit of the range is determined based on requirements for machining process time (tact time for machining). For example, in order to achieve the highly accurate uniformity of 2 μm or less, it is necessary to make surface roughness

of the laminate 5 at a certain level to achieve that uniformity in the coring process. The purpose of this is to make stock removal smaller for the inner end face in the later chamfering process, thereby preventing a crack from occurring. In this regard, the abrasive grit size of the inner diameter blade 20b may be preferably 150 or greater. Further, from the aspect for obtaining acceptable machining process time, the abrasive grit size of the inner diameter blade 20b may be preferably 800 or less.

[0057]

On the other hand, a range of the abrasive grit size of the outer diameter blade 20a may be coarser than that of the inner diameter blade 20b. In order to achieve the target concentricity (5 μm or less) of the inner and outer circumferences for the glass substrate for magnetic disk, the abrasive grit size of the outer diameter blade 20a may be preferably 120 or greater. In another aspect, the outer machining surface has longer machining amount (that is, longer circumference in machining), which results in increased resistance in machining. In this regards, the abrasive grit size of the outer diameter blade 20a may be preferably 600 or less such that the increased resistance in machining does not influence on proper machining.

[0058]

With the integrated coring machine 20 according to the present embodiment, the top of the inner diameter blade 20b may be preferably protruded downward in comparison with that of the outer diameter blade 20a. This allows a machining axis to be stable because the machining for the outer circumference is advanced a little earlier than that for the inner circumference. Consequently, because the uniformity of the outer machining surface of the laminate is likely to be less, the concentricity of the outer machining surface and the inner machining surface is also likely to be less.

[0059]

As described above, the direction of the revolution of the integrated coring machine 20 and the flow direction of coolant are arranged such that coolant is well drawn into the outer machining surface 32. In other words, at least one of a position where coolant is provided, a flow rate and a diameter of coolant flow is to be controlled, so that coolant is well drawn into a gap between the laminate and the outer diameter blade 20a of the revolving integrated coring machine 20. More specifically, the flow direction of coolant is a direction of a vector ("combined vector") that is obtained to combine the tangent vector (lateral component) with and the vector (downward component). The tangent vector (lateral component) is tangential to the cylindrical outer machining surface of the coring machine 20 (namely, the outer surface of the coring machine) from the nozzle 16, and is substantially consistent with a revolving direction of the integrated coring machine 20 on a plane orthogonal to the direction of lamination. The

vector (downward component) has a downward direction of lamination.

The above combined vector has preferably a direction from the nozzle 16 to a tangent point on a line of intersection of the outer surface of the outer diameter blade 20a and the top surface of the laminate.

Note that, in the above explanation, provision direction of coolant from the nozzle 16 is, from the plan view, the direction of the tangent vector tangential to the outer machining surface 32 of the integrated coring machine 20; however, provision direction of coolant from the nozzle 16 may be, from the plan view, a direction of a tangent vector tangential to the outer machining surface of the laminate, because the thickness of the outer machining blade 20a of the integrated coring machine 20 is relatively small in comparison with the diameter of the laminate.

[0060]

Also note that, depending on the revolution of the coring machine and/or the flow rate of coolant, a target position where coolant is provided (hit) (called hereinafter simply “target position”) may be adjusted. For example, the target position may be adjusted to be slightly the more central point than the above-mentioned tangent point. The target position may be adjusted to be the more upper point than the above-mentioned tangent point, while maintaining the contact of the integrated coring machine 20 and the coolant flow. This allows coolant to be well drawn into the top of the outer machining blade, even when the blade descends inside of the laminate as the machining proceeds. Thus, coolant properly works for discharge of sludge and cooling of the machining portion, thereby preventing uniformity of the outer machining surface of the laminate from being worse.

[0061]

Then target position of coolant will be further explained with reference to Fig. 5. Fig. 5 is a view illustrating the target position for coolant provision from the plan view. Fig. 5 illustrates a position of the nozzle that provides coolant and the circumference of the outer machining surface 32 of the coring machine (the outer surface of the coring machine, which is circular in the plan view). In Fig. 5, an angle is defined to be α (degree) which is formed with a line connecting the nozzle exit and a point on the circumference of the outer machining surface 32 and a tangential line of that point. For example, α is equal to zero (degree) ($\alpha=0$) when coolant is provided from the nozzle toward a direction of the tangential line of the outer machining surface 32 (see “d1” in Fig. 5), while α is equal to 90 (degree) ($\alpha=90$) when coolant is provided from the nozzle toward a center of the outer machining surface 32 (see “d0” in Fig. 5). Here, coolant is preferably provided in a way that α ranges from 0 (degree) to 15 (degree). That is, coolant is not necessarily provided in a way that α is equal to zero (degree) ($\alpha=0$). Because coolant flow (jet) from the nozzle has a certain diameter, coolant is likely to be well drawn into

the outer machining surface 32 even when the coolant flow is directed to more central side ($\alpha=0$ to 15) than the case of $\alpha=0$. Note that, although not clear from Fig. 5 of plan view, the provision direction of coolant from the nozzle is a direction of a combined vector of two vectors; that is, a vector (lateral component; see Fig. 5) consistent with a revolving direction of the integrated coring machine 20 on a plane orthogonal to the direction of lamination ($\alpha=0$ to 15), and a vector (downward component) of the downward direction of lamination.

Also note that, in the above explanation, provision direction of coolant from the nozzle 16 is defined based on the outer machining surface 32 of the integrated coring machine 20; however, provision direction of coolant from the nozzle 16 may be defined based on the outer machining surface of the laminate, because the thickness of the outer machining blade 20a of the integrated coring machine 20 is relatively small in comparison with the diameter of the laminate.
[0062]

The flow rate of coolant will be explained below. Assume that the flow rate of coolant is divided into two components, that is, a lateral velocity on a plane orthogonal to the direction of lamination, and a downward velocity in the direction of lamination. Here, preferably the lateral velocity is substantially identical to a linear velocity of the outer machining blade 20a of the integrated coring machine 20 at the target position of coolant. This allows that coolant provided is unlikely to be reflected by the revolving coring machine, and that coolant is likely to infiltrate (that is, be drawn into) the gap between the laminate and the outer diameter blade 20a of the revolving integrated coring machine 20. That is, even when the top of the outer diameter blade 20a proceeds inside of the laminate, coolant provided is likely to reach the machining portion (that is, top of the outer diameter blade). Consequently, during the coring process to the laminate, coolant properly works for discharge of sludge and cooling of the machining portion, thereby preventing uniformity of the outer machining surface of the laminate from being worse.

Note that a diameter of the nozzle is preferably 2 to 8 mm, and that the nozzle is preferably designed such that the diameter of the coolant flow does not expand as it flows forward from the nozzle.

[0063]

As explained above, coolant provided from the nozzle 16 is unlikely to be reflected by the revolved coring machine 20, and coolant is therefore well drawn into the outer machining surface 32. As a result, sludge is evenly removed from the circumference of the outer machining surface, and stock removal is made substantially even over the entire circumference of the outer machining surface of the laminate, thereby achieving excellent level of uniformity in the outer machining surface of the laminate. Further, even when the top of the outer diameter blade proceeds inside of the laminate, coolant properly works for discharge of sludge and

cooling of the machining portion. This allows preventing uniformity of the outer machining surface of the laminate from being worse.

[0064]

(4) Chamfering Process

After the coring process, the chamfering process is performed to form a chamfer surface on edge portions of the laminate 5 (outer end face and inner end face). In the chamfering process, the outer surface and the inner surface of the laminate, which is machined to be cylindrical, are chamfered using metal-bond blade including diamond abrasive grains.

[0065]

(5) End Polishing Process

Next, edge-polishing is performed for the laminate of the sheet glass materials. In the edge-polishing, mirror finishing is performed for the outer end face and the inner end face of the laminate of the sheet glass materials by brush polishing. At this point, slurry that includes fine particles such as cerium oxide as the loose abrasive grain is used. The contamination of dust and damage such as a flaw are removed by performing the edge polishing. Therefore, generation of ions such as a sodium and potassium which cause corrosion can be prevented.

[0066]

(6) Laminate Separating Process

After the coring process, the chamfering process, and the end polishing process for the laminate 5, the laminate separating process is performed for separating each of the annular sheet glass material from the laminate 5. For example, the laminate is immersed in hot water (80 to 90 degrees Celsius) such that the bonding agents 5b are softened and each of the annular sheet glass material is separated from the laminate 5.

[0067]

(7) Grinding Process using Fixed Abrasive Grain

The grinding process using fixed abrasive grain is performed for the principal surfaces of each annular sheet glass materials by use of a grinding device. Stock removal of the grinding is around several μm to 10 μm . The grinding device includes a pair of surface plates (a lower surface plate and an upper surface plate) between which a plurality of annular sheet glass materials are sandwiched. Either the lower surface plate or the upper surface plate, or the both are moved such that the plurality of annular sheet glass materials and the surface plate(s) are relatively moved; thereby grinding the principal surfaces of each annular sheet glass materials.

[0068]

(8) First Polishing (principal surface polishing) Process

Next, the first polishing is performed for the ground principal surfaces of the annular sheet glass material. Stock removal of the first polishing is around several μm to 50 μm for example. The first polishing is intended to remove the flaw and the deformation left on the principal surface after the grinding using the fixed abrasive grain. In the first polishing process, for example, the device used in the grinding process using the fixed abrasive grain may be again used. At this point, the first polishing differs from the grinding using the fixed abrasive grain in the following points; that is, in the first polishing, slurry of turbid loose abrasive grains is used instead of the fixed abrasive grains (grinding pad), and a resin polisher is used.

For example, the slurry of turbid fine particles such as cerium oxide (particle size: diameter of about 1 μm to about 2 μm) is used as the loose abrasive grains used in the first polishing.

[0069]

(9) Chemically Strengthening Process

After the first polishing, the sheet glass material is chemically strengthened.

For example, a mixed solution of potassium nitride (60 weight percent) and sodium sulfate (40 weight percent) may be used as a chemically strengthening solution. In the chemically strengthening, the chemically strengthening solution is heated to 300°C to 400°C for example, and the washed sheet glass material is pre-heated to 200°C to 300°C for example. Then, the sheet glass material is immersed in the chemically strengthening solution for three to four hours. Preferably, in order that the whole principal surfaces of the sheet glass material are chemically strengthened, the immersing is performed while the plural sheet glass materials are accommodated in a holder by retaining the sheet glass materials at the end faces.

When the sheet glass material is immersed in the chemically strengthening solution, the lithium ion and the sodium ion in the surface layer of the sheet glass material are replaced with the sodium ion and the potassium ion which have relatively larger ion radiuses in the chemically strengthening solution, respectively, thereby strengthening the sheet glass material. The sheet glass material to which the chemically strengthening treatment is performed is washed. For example, after washing the sheet glass material using the sulfuric acid, the sheet glass material is washed using pure water and IPA (isopropyl alcohol).

[0070]

(10) Second Polishing (final polishing) Process

Next, the second polishing is performed for the sheet glass material to which the chemically strengthening treatment and washing are sufficiently performed. For example, stock removal of the second polishing is about 1 μm . In the second polishing process, for example, the device used in the grinding process using the fixed abrasive grain and the first polishing

process may be again used. At this point, the second polishing differs from the first polishing in the following points; that is, in the second polishing, the kind and particle size of loose abrasive grains in use differ, and hardness of the resin polisher also differ.

For example, slurry of turbid fine particles such as colloidal silica (particle size: diameter of 0.01 to 0.1 μm for example) is used as the loose abrasive grain used in the second polishing.

The polished sheet glass material is then washed. A neutral detergent, pure water, and IPA are used in the washing. After completing the second polishing process, a glass substrate for magnetic disk is obtained.

[0071]

- Magnetic Disk

A magnetic disk is manufactured in the following sequence based on a glass substrate for magnetic disk (which may be called "glass substrate" hereinafter).

The magnetic disk includes, in order closer to the principal surface, at least an adhesive layer, an underlying layer, a magnetic layer (magnetic recording layer), a protective layer, and a lubricant layer on the principal surface of the glass substrate.

For example, a glass substrate is introduced into a film formation apparatus to which vacuum drawing has been performed, and then the adhesive layer through the magnetic layer is sequentially deposited on the principal surface of the glass substrate in the ambient Ar based on DC magnetron sputtering method. For example, CrTi is applied for the adhesive layer, while CrRu is applied for the underlying layer. After the above deposition, the protective layer of C_2H_4 is deposited based on CVD (Chemical Vapor Deposition) method for example, and then nitriding treatment introducing Nitrogen on the surface is performed in the same chamber to obtain a magnetic recording media. After that, PFPE (polyfluoropolyether) is coated on the protective layer based on Dip-coat method to form the lubricant layer.

[0072]

- Modifications

Next, modified manufacturing method of glass substrate for magnetic disk according to the first embodiment will be explained below. The modified manufacturing method includes the different coring process from the one already described. In the modified manufacturing method, processes other than the coring process may be the same as the corresponding processes already described. Referring now to Fig. 6, the modified coring method will be explained.

[0073]

Fig. 6 is a view illustrating a modified machining system for machining the laminate 5 in the coring process according to the modified embodiment. As illustrated in Fig. 6, the

machining system also includes a main device 10, a shaft 12, a revolving part 14, a coolant providing hoses 15, and an integrated coring machine 20. The shaft 12, the coolant providing hoses 15, and the integrated coring machine 20 may be the same as already described.

The revolving part 14 is provided at the outer circumference of the main device 10 in the machining system according to the modified embodiment. Further, the coolant providing hoses 15 (15a, 15b) is attached to the revolving part 14. The main device 10 may preferably drive the revolution of the revolving part 14 around the same axis as the revolution axis of the outer machining blade independently of the revolution of the integrated coring machine 20. Preferably, the revolving part 14 revolves in the same direction as the integrated coring machine 20.

The flow direction of coolant provided to the outer machining blade is the same as already described.

[0074]

During the coring process according to the modified embodiment, the machining for the laminate 5 by use of the machining system illustrated in Fig. 6 is performed as follows.

First, as illustrated in Fig. 6, the integrated coring machine 20 is located above the laminate 5 placed on a mounting stand 30. Next, the shaft 12 is revolved while the main device 10 is moved down. The revolution of the shaft 12 is around 1,500 to 15,000 rpm. As a result, the integrated coring machine 20 is revolved around the center axis of the shaft 12, while moved in the direction of lamination of the laminate 5 (that is, downward direction).

The main device 10 drives the revolving part 14. The revolution of the revolving part 14 is around 10 to 100 rpm. As a result, the coolant providing hoses 15 attached to the revolving part 14 revolves around the same axis as the revolution axis of the outer machining blade.

[0075]

The integrated coring machine 20 is moved down until it reaches to the hollows 30a, 30b of the mounting stand 30. During the machining for the laminate 5 by use of the integrated coring machine 20, coolant is provided from the nozzle 16 (16a, 16b) of the coolant providing hoses 15 and the nozzle 17a of the coolant providing hoses 17.

[0076]

According to the modified embodiment, the nozzle positioned toward the outer machining blade is revolved around the same axis as the revolution axis of the outer machining blade while coolant is provided to the outer machining surface of the integrated coring machine 20. As a result, sludge is more evenly removed from the circumference of the outer machining surface, and stock removal is made substantially even over the entire circumference of the

outer machining surface, thereby achieving more excellent level of uniformity for the outer machining surface of the laminate.

[0077]

- EXAMPLES

Hereinafter, the first embodiment according to the present invention will be further explained with examples. Note that the present inventions are not limited to the examples explained below.

[0078]

(1) Manufacturing of Molten Glass

Weights of ingredients were measured such that the following composition of glass was obtained, and the ingredients were mixed. The mixed ingredients were cast into a melting vessel, heated, melted, clarified, and stirred to finally obtain homogeneous molten glass excluding bubbles or non-melted substances. Bubbles, non-melted substances, extracts of crystal, and refractory substances or platinum from the melting vessel were not included in the obtained molten glass.

Principal composition of glass: 58 to 75% SiO_2 , 5 to 23% Al_2O_3 , 3 to 10% Li_2O , and 4 to 13% Na_2O

[0079]

(2) Manufacturing of Laminate

Sheet glass materials, each of which is 1.0 mm thick, were obtained with the float method in which the molten glass of the above described composition were continuously run into a bath filled with molten metal including tin. The surface roughness R_a of the sheet glass materials was 0.01 μm . The obtained sheet glass material was cut to produce sheet glass materials, each of which had a square shape for a basis of a glass substrate for magnetic disk. Then, a laminate was prepared by sequentially coating visible light curing resin as bonding agent evenly on the principal surfaces of the cut sheet glass materials and by laminating the sheet glass materials. Further, intervened resin was hardened by irradiating visible rays of light while pressing the both sides of the laminate, thereby preventing the sheet glass materials from being separated.

Exemplary Laminate

- Size of sheet glass material: 75 mm x 75 mm
- Number of laminated sheet glass materials: 25
- Bonding agent: visible light curing resin (ADELL Corporation, CLEARPRESTO (Registered trademark) CP4022)
- Thickness of bonding agent in the laminate: 30 μm

[0080]

(3) Manufacturing of Laminate

As illustrated in Fig. 2, the laminate was fixed on the mounting stand and machined (drilled) for coring. The machining was performed with an integrated coring machine revolved at 5,000 rpm while minutely vibrating in the upward and downward direction with an ultrasonic generator (20 kHz, 5 to 7 μ m amplitude). As a result, annular sheet glass materials of 2.5 inches (inner diameter: 20 mm, outer diameter: 65 mm) were obtained. Here, diameters of the inner diameter blade and the outer diameter blade were determined such that the inner diameter of each annular sheet glass material became 20 mm while the outer diameter became 65 mm after the machining for coring and the subsequent chamfering. Note that thickness of each machining blade was 2 mm.

[0081]

During the machining, coolant of 17 liter per minute was provided from the nozzle 17a (see Fig. 2) to the inner machining surface of the coring machine. CHEMICOOL (Registered trademark) C-798S (CHEMIC Co., Ltd.) was used as coolant. As illustrated in Fig. 4, coolant was provided to the outer machining surface of the coring machine from two nozzles 16a, 16b (see also Fig. 2) positioned point-symmetrical to the revolution axis of the integrated coring machine. Coolant of 20 liter per minute was provided from the nozzles 16a, 16b to the outer machining surface of the coring machine. More specifically, the flow direction of coolant was a direction of a vector (combined vector) that combined the tangent vector (lateral component) and the vector (downward component). The tangent vector (lateral component) was tangential to the cylindrical outer machining surface of the coring machine from the nozzle 16, and was consistent with a revolving direction of the integrated coring machine 20 on a plane orthogonal to the direction of lamination. The vector (downward component) had a downward direction of lamination. The above combined vector had a direction from the nozzle to a tangent point on a line of intersection of the outer surface of the outer diameter blade and the top surface of the laminate. Lateral velocity of the coolant provided, which was a lateral component of flow rate of coolant on a plane orthogonal to the direction of lamination, was 18 m/sec. In this way, coolant was well drawn into the machining portion during the machining.

Note that a linear velocity of the outer machining blade of the coring machine is determined to be 18 (m/sec) ($= 69 \text{ (mm)} \times \pi \times 5,000 \text{ (rpm)} / 60 \text{ (sec/min)}$). 69 (mm) as a diameter in the calculation was considered to include the thickness (2 mm) of the blade. That is, the lateral velocity of coolant flow was substantially identical to the linear velocity of the outer machining blade.

Metal-bond blades that includes abrasive grains of diamond (Grain binder: Cast iron)

were used as the outer diameter blade and the inner diameter blade of the integrated coring machine. The abrasive grit size of the inner diameter blade was 600, while that of the outer diameter blade was 300.

[0082]

After the machining for coring, the chamfering process was performed for the annularly machined outer side surface and inner side surface to form chamfer surfaces by use of electrocoat-bond blades that include abrasive grains of diamond. The abrasive grit size of the metal-bond blade was 800.

[0083]

(4) Laminate Separating and End Polishing

Next, the laminate was immersed in hot water (80 to 90 degrees Celsius) such that each of the annular sheet glass material was separated from the laminate. At this point, abnormal status of the surfaces of each annular sheet glass material was never observed. Then, mirror finishing was performed for the outer end face and the inner end face of each sheet glass material by brush polishing using slurry that includes cerium oxide as the loose abrasive grains. Finally, glass substrates for evaluation were obtained.

[0084]

After the machining for coring, samples (annular sheet glass materials) were partially separated from the laminate without chamfering. These samples are hereinafter called "Working Example 1" of the annular sheet glass materials.

Further, apart from the above process, a laminate was prepared for Comparative Example. The laminate was machined for coring such that the flow direction of coolant for the outer machining surface was not a direction tangential to the tangential line of the outer machining surface from each nozzle, but a direction to the center of the circular outer machining surface from each nozzle, from a view consistent with a direction of lamination of the laminate (that is, from a plan view). Then, the plurality of the annular sheet glass materials were separated from the laminate. The separated annular sheet glass materials are hereinafter called "Comparative Example 1".

Further, laminates were prepared for Reference Examples. These laminates were machined with different flow directions of coolant in a way that target positions of coolant were adjusted between those of Working Example 1 and Comparative Example 1, while the target positions, where coolant was hit, were set on a line of intersection of the outer surface of the outer diameter blade and the top surface of each laminate. More specifically, angle α (see Fig. 5), which was formed with a line connecting the nozzle exit and a point on the circumference of the outer machining surface and a tangential line of that point, were adjusted to be 15, 30, and 60

(degree). Then, the plurality of the annular sheet glass materials were separated from the laminates. The separated annular sheet glass materials are hereinafter called "Reference Examples 1, 2 and 3". "Reference Examples 1, 2 and 3" corresponds to the above α of 15, 30, and 60 (degree) respectively. Note that, the provision direction of coolant for Working Example 1 is "d1" in Fig. 5, while that for Comparative Example 1 is "d0".

Also note that, when manufacturing Working Example, Comparative Example, and Reference Examples, the target positions were set on a line of intersection of the outer surface of the outer diameter blade and the top surface of each laminate. Lateral velocity of the coolant provided, which was a lateral component of flow rate of coolant on a plane orthogonal to the direction of lamination, was 18 m/sec constant.

[0085]

(5) Evaluation of Uniformity and Crack

For twenty-five sheet glass materials of each of Working Example, Comparative Example, and Reference Examples, uniformity of the outer circumference, and concentricity of the outer circumference and the inner circumference were measured. Then, the maximum measured values was determined as the uniformity and the concentricity of each Example. Uniformity of the outer circumference of Working Example 1 and Comparative Example 1, as measured, were 2.0 μm and 6.0 μm respectively. It is appreciated by the skilled in the art from this result that uniformity of the outer circumference is improved after the machining for coring by providing coolant such that the flow direction of coolant for the outer machining surface is, from the plan view, a direction of a tangent vector tangential to the cylindrical outer machining surface from each nozzle from a view consistent with a direction of lamination of the laminate, and that the direction of the tangent vector is substantially consistent with the direction of revolution of the integrated coring machine. Note that the measured concentricity was excellently 1.5 μm for Working Example 1.

Uniformity of the outer circumference of Reference Examples 1, 2 and 3 were 2.0 μm , 3.3 μm and 5.2 μm respectively. The uniformity of Reference Example 1 was substantially the same as that of Working Example 1, because coolant flow from the nozzle had a certain diameter, and that amount of coolant drawn into the outer machining surface in manufacturing Reference Example 1 was substantially the same as that in manufacturing Working Example 1 even when the coolant flow was directed to more central side of the coring machine.

[0086]

(6) Other Examples

Further, uniformity of the inner circumference of twenty-five glass substrates obtained through the above (1) to (5) processes was measured. It was observed whether cracks existed

on the inner end face of the glass substrate by use of a laser microscope. The glass substrate obtained through the above (1) to (5) processes is called "Working Example 2".

The uniformity of the inner circumference of Working Example 2 was 1.3 μm , which is the maximum value of twenty-five glass substrates. There were no cracks on the inner and the outer end faces of Working Example 2, as observed by use of the laser microscope. As described, it is appreciated by the skilled in the art that glass substrates of targeted 2.0 μm or less in uniformity of the inner and the outer circumferences without any crack are obtainable by way of the manufacturing method according to the present embodiment.

[0087]

Further, a laminate was prepared for "Working Example 3". As illustrated in Fig. 6, Working Example 3 was manufactured with two nozzles revolving in the same direction as the revolving direction of the integrated coring machine. The revolution of the nozzles was 10 rpm. Uniformity of the outer circumference of Working Example 3, as measured, was 1.5 μm (the maximum of twenty-five sheet glass materials). That is, the uniformity of the outer circumference of Working Example 3 was proven to be further improved in comparison with that of Working Example 1.

What is claimed is:

1. A manufacturing method of glass substrate for magnetic disk, the method comprising the steps of
preparing a laminate that is formed with a plurality of sheet glass materials laminated, and

machining the laminate by revolving and moving a coring machine in the direction of lamination, the coring machine concentrically having an outer diameter blade of large diameter and an inner diameter blade of small diameter, while providing an outer machining surface which is the outer surface of the outer diameter blade of the coring machine with machining fluid, the outer diameter blade and the inner diameter blade contacting the sheet glass materials,

wherein a direction of the revolution of the coring machine and a flow direction of the machining fluid are arranged such that the machining fluid is drawn into the outer machining surface, and

wherein the machining fluid is provided with a nozzle, and the flow direction of the machining fluid is a direction of a first vector directing from the nozzle to a first point on the outer machining surface of the rotating outer diameter blade, and

wherein the flow direction of the machining fluid is substantially consistent with a revolving direction of the coring machine such that an angle between a lateral component of the first vector and a tangential velocity vector of the first point ranges from 0 to 15 degrees, and

wherein said first vector has a downward component.

2. The manufacturing method of glass substrate for magnetic disk according to claim 1,

wherein said angle is 0 degree.

3. The manufacturing method of glass substrate for magnetic disk according to claim 1 or 2, wherein the machining fluid is provided to the outer machining surface by use of a plurality of nozzles, the nozzles being positioned substantially evenly over the entire circumference of the outer diameter blade in said machining.

4. The manufacturing method of glass substrate for magnetic disk according to claim 1 or 2, wherein the machining fluid is provided to the outer machining surface by use of single or a plurality of nozzles, the nozzle or nozzles positioned toward the outer diameter blade and revolved concentrically with the outer diameter blade.