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.

[0088]

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

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

[0089]

In the manufacturing method according to the present embodiment, (1) Forming Process of Sheet Glass Material and Lapping Process, and (2) Laminate Preparation Process, may be the same as the first embodiment, and omitted for the sake of brevity.

[0090]

(3) Laminate Immersion Process

The laminate immersion process is a process for immersing the laminate in coolant. Referring now to Fig. 7, the laminate immersion process will be explained below. FIG. 7 is a view illustrating the laminate immersion process according to the present embodiment. As illustrated in Fig. 7, an immersion vessel 40 is filled with coolant 42 so that the laminate 5 is sufficiently immersed. The mounting stand 30 for mounting the laminate 5 is located on the bottom of the immersion vessel 40. In the laminate immersion process according to the present embodiment, the laminate 5 is mounted on the mounting stand 30, and is therefore immersed in

coolant 42.

Coolant 42 is preferable to be material that does not dissolve the bonding agent of the laminate because coolant contacts the laminate for relatively long period. Coolant 42 may be water-soluble substance that includes Alkylene glycol or Ethanolamine, for example. Coolant 42 may be, for example, CHEMICOOL (Registered trademark) C-798S.

[0091]

Here, an inlet 44 and an outlet 46 are provided in the immersion vessel 40. The inlet 44 provides the immersion vessel 40 with coolant 42. The outlet 46 drains coolant 42 from the immersion vessel 40.

A filter 48 and a pump 50 are provided between the inlet 46 and the outlet 44. The filter 48 removes sludge produced during the later-described coring process. The pump 50 raises coolant 42 drained from the outlet 46, to the inlet 44. The inlet 46, the pump 50, and the inlet 44 are interconnected with pipes 52 as illustrated in Fig. 7.

[0092]

Coolant 42 drained from the outlet 46 is again provided to the immersion vessel 40 via the filter 48 and the pump 50; that is, coolant 42 is circulated. With coolant 42 circulated, it is possible to prevent sludge produced during the later-described coring process from staying inside of the immersion vessel 40.

Note that coolant 42 may be preferably circulated in the present embodiment; however, the present invention may be applied for a system in which coolant is not circulated.

[0093]

(4) 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 Fig. 8, the coring process (machining process) according to the present embodiment will be explained. FIG. 8 is a view illustrating a machining system for machining the laminate 5 which is immersed in the immersion vessel 40 filled with coolant 42 in the coring process according to the second embodiment. Note that the integrated coring machine used in the coring process according to the present embodiment may be the same as illustrated in Fig. 3.

[0094]

As illustrated in Fig. 8, the machining system according to the present embodiment includes a main device 10, a shaft 12, 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.

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.

[0095]

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 of the laminate 5.

[0096]

As illustrated in Fig. 8, 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 and the shaft 12 to integrally move up and down.

[0097]

Here, 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 (see Fig. 3).

Further, as illustrated in Fig. 8, 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.

[0098]

As illustrated in Fig. 8, the shaft 12 is equipped inside with a 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. Note that, with the present method, because the integrated coring machine 20 and the laminate 5

are sufficiently immersed in coolant during the machining, coolant may be provided to the inner machining surface to a certain extent without any additional equipment. Thus, coolant provision from the coolant providing tube 17 may not be indispensable.

[0099]

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. 8.

First, as illustrated in Fig. 8, 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).

[0100]

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, preferably, coolant 42 is provided from the inlet 44 to the immersion vessel 40, while coolant 42 is provided from the nozzle 17a of the coolant providing hoses 17 to the inner machining surface of the laminate 5. This allows coolant flow to direct from the inner machining surface to the outer machining surface. Then, during the coring process to the laminate, coolant properly works for discharge of sludge and cooling of the machining portion, even when the inner and the outer machining blades proceeds inside of the laminate as the machining proceeds. This allows preventing uniformity of the outer and the inner machining surfaces of the laminate from being worse.

[0101]

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. The purpose of this is 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.

[0102]

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.

[0103]

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.

[0104]

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 more 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.

[0105]

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 during the machining because the outer circumference is machined a little earlier than the inner circumference is.

[0106]

As described above, in the coring process according to the present embodiment, the laminate 5 is machined while immersed in the immersion vessel 40 filled with coolant 42. Thus, coolant 42 is evenly provided between the outer machining surface and the outer machining blade 20a. 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, thereby achieving excellent level of uniformity for the outer machining surface.

[0107]

In the manufacturing method according to the present embodiment, processes that follow the coring process: namely Chamfering Process; End Polishing Process; Laminate Separating Process; Grinding Process using Fixed Abrasive Grain; First Polishing (principal surface polishing) Process; Chemically Strengthening Process; and Second Polishing (final polishing) Process, may be the same as the corresponding processes described in accordance with the first embodiment, and are omitted for the sake of brevity.

[0108]

- EXAMPLES

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

[0109]

(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

[0110]

(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 Ra 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

[0111]

(3) Laminate Immersion Process

As illustrated in Fig. 7, the laminate was immersed in a immersion vessel filled with coolant. CHEMICOOL (Registered trademark) C-798S (CHEMIC Co., Ltd.) was used as coolant. Coolant of 20 liter per minute was provided from an inlet, and circulated. A bag filter was used as a filter for coolant.

[0112]

(4) Manufacturing of Laminate

As illustrated in Fig. 8, 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 μm amplitude). As a result, annular sheet glass materials of 2.5 inches (inner diameter: 20 mm, outer diameter: 65 mm) were obtained.

During the machining, coolant of 17 liter per minute was provided to the inner machining surface of the laminate. 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. Thickness of each machining blade was 2 mm.

[0113]

After the machining for coring, the laminate was extracted from the immersion vessel, and 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.

[0114]

(5) 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 included cerium oxide as the loose abrasive grains. Finally, glass substrates for evaluation were obtained.

[0115]

(6) Evaluation of Uniformity and Crack

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 not immersed in the immersion vessel, but coolant was provided to the laminate from two coolant providing nozzles while being machined. Chamfering was not performed for the machined laminate. 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".

[0116]

Uniformity of the outer circumference of Working Example 1 and Comparative Example 1, as measured, were 1.3 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 with the laminate immersed in coolant (Working Example 1).

[0117]

Further, uniformity of the inner circumference of the glass substrate 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 1.4 μm. There

were no cracks on the inner end face 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 without any crack are obtainable by way of the manufacturing method according to the present embodiment.

[0118]

Further, laminates were prepared for other Working Examples by modifying the machining condition, specifically applying different abrasive grit size from that for Working Example 1. Specifically, when manufacturing "Working Example 3", abrasive grit size of the inner machining blade was 600, while abrasive grit size of the outer machining blade was 600. When manufacturing "Working Example 4", abrasive grit size of the inner machining blade was 600, while abrasive grit size of the outer machining blade was 800. Uniformity of the outer circumference of Working Examples 3 and 4, as measured, were 2.2 μm and 4.5 μm respectively (the maximum of twenty-five sheet glass materials). Uniformity of the outer circumference of Working Examples 3 and 4 was greater than that of Working Examples 3, because the outer machining surface had more machining amount (that is, longer circumference in machining), which resulted in increased resistance in machining due to the abrasive grit size of the outer machining blade being substantially the same as or greater than that of the inner diameter blade.

[0119]

All examples and conditional language recited herein are intended for pedagogical purposes to aid the reader in understanding the invention and the concepts contributed by the inventor to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions, nor does the organization of such examples in the specification relate to a showing of the superiority and inferiority of the invention. Although the embodiment(s) of the present inventions have been described in detail, it should be understood that the various changes, substitutions, and alternations could be made hereto without departing from the spirit and scope of the invention.

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 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.

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

wherein 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.

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

wherein 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.

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 a plurality of nozzles, the nozzles being positioned substantially evenly over the entire circumference of the outer diameter blade in said machining.

5. 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.

6. The manufacturing method of glass substrate for magnetic disk according to any of

claims 1 to 4, wherein uniformity of the outer circumference of the glass substrate for magnetic disk is 5 μm or less.

7. 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.

8. 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.

9. The manufacturing method of glass substrate for magnetic disk according to claim 7 or 8, further comprising circulating the machining fluid in which the laminate is immersed.

10. The manufacturing method of glass substrate for magnetic disk according to any of any claims 7 to 9, wherein the abrasive grit size of the inner diameter blade is greater than that of the outer diameter blade.

11. The manufacturing method of glass substrate for magnetic disk according to claim 10, wherein 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.

12. The manufacturing method of glass substrate for magnetic disk according to any of claims 7 to 11, further comprising edge-polishing for polishing end faces of the sheet glass material.

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 well 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 substantially consistent with a revolving direction of the coring machine such that an angle between a lateral component of the vector directing from the nozzle to a point on the outer machining surface of the rotating outer diameter blade and a tangential velocity vector of said point ranges from 0 to 15 degrees, and said vector has a downward component.

2. The manufacturing method of glass substrate for magnetic disk according to claim 1, wherein said angle is 0 degrees.

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.