DESCRIPTION

[Title of Invention]

ANNEALING PLATE, METHOD FOR MANUFACTURING ANNEALING PLATE, AND METHOD FOR MANUFACTURING SUBSTRATE

[Technical Field]

[0001] The present invention relates to an annealing plate to be used in an annealing process for annealing a blank, a method for manufacturing the annealing plate, and a method for manufacturing a substrate.

[Background Art]

[0002] Nowadays, in order to record data, hard disk drives (HDDs) are incorporated in personal computers, DVD (Digital Versatile Disc) recording apparatuses, and the like. A magnetic disk obtained by providing a magnetic layer on a substrate is used in a hard disk drive, and magnetic recording information is recorded in, or read from, the magnetic layer by using a magnetic head that is made to float slightly above the surface of the magnetic disk. A metal substrate (an aluminum substrate) or a glass substrate having a property of being unlikely to undergo plastic deformation compared to a metal substrate or the like is preferably used as this magnetic-disk substrate.

[0003] A magnetic-disk glass substrate is produced by performing machining such as grinding and polishing on a plate-shaped glass blank, for example. An annealing process may be performed on the glass blank in order to eliminate warping before machining is performed. A method for performing heat treatment on a stacked body obtained by stacking plates, which are called setters, and glass blanks in an alternating manner is known as a conventionally performed annealing process (PTL 1). By performing such an annealing process, it is possible to not only eliminate warping but also improve the flatness of the glass blank and make the surface properties of the glass blank more favorable.

[Citation List]

[Patent Literature]

[0004] [PTL1]: Japanese Patent No. 6238282

[Summary of Invention]

[Technical Problem]

[0005] With the above-described conventional method, the glass blanks are collected by removing the setters and the glass blanks in an alternating manner from the stacked body after the annealing process is performed. However, when a setter is removed, a glass blank may stick to the lower surface of the setter and be removed from the stacked body together with the setter. In this case, operation for separating (detaching), from the setter, the glass blank stuck to the setter is required to collect the glass blank, and thus operation efficiency and the productivity of glass substrates will decrease. Also, the glass blank that is stuck to the lower surface of the setter and is lifted may fall and become cracked, chipped, or scratched. There is a risk that a glass blank damaged in this manner will be unsuitable as a base plate of a glass substrate, and the yield of glass substrates will decrease.

[0006] The present invention aims to provide an annealing plate with which the annealing plate and a blank that are stacked can be easily separated from each other. Also, the present invention aims to provide a method for manufacturing such an annealing plate, and a method for manufacturing a magnetic-disk substrate, using such an annealing plate.

[Solution to Problem]

[0007] One aspect of the present invention is an annealing plate, which is one of a plurality of plates that are to be used in an annealing process for annealing a plate-shaped blank and are to be stacked to hold the blank from both sides,

the annealing plate including: a pair of main surfaces, at least one of the main surfaces coming into contact with the blank, ~~and~~

one or more through-holes that are open in the main surfaces and pass through the plate~~.~~

the main surface has an arithmetic average roughness that is adjusted such that air flows into gaps between the plate and the blank that are stacked,

the gaps are continuous with the through-holes,

a position at which a circular hole is to be formed is set in the blank, and

the through-hole is open in a region of the main surface of the plate that comes into contact with a portion of the blank in which the position is set.

~~[0008] It is preferable that the main surface has an arithmetic average roughness that is adjusted such that air flows in between the plate and the blank that are stacked.~~

[0009] It is preferable that a sum of arithmetic average roughnesses of the main surface of the plate and a main surface of the blank that comes into contact with the main surface is 0.2 μm or more.

[0010] It is preferable that an arithmetic average roughness of the main surface of the plate is larger than an arithmetic average roughness of a main surface of the blank that comes into contact with the main surface.

[0011] It is preferable that an arithmetic average roughness of the main surface of the plate is 0.2 to 1.0 μm.

[0012] It is preferable that at least one of the through-holes is open in the main surface of the plate such that an edge of the plate surrounding the at least one through-hole comes into contact with a main surface of the blank.

[0013] It is preferable that a shape of the through-holes that are open in the main surfaces of the plate is a circular shape, and

the through-holes have a diameter of 1 to 6 mm.

[0014] It is preferable that a plurality of the through-holes are provided, and are dispersed and are open in the main surfaces of the plate.

[0015] It is preferable that, when the main surfaces of the plate are divided into regions having equal areas, the same number of through-holes are arranged in the respective regions.

~~[0016] It is preferable that a position at which a circular hole is to be formed is set in the blank, and~~

~~the through-hole is open in a region of the main surface of the plate that comes into contact with a portion of the blank in which the position is set.~~

[0017] It is preferable that a side wall of the plate that surrounds the through-hole is chamfered such that a cross-sectional area of the through-hole extending along a direction that is parallel to the main surface of the plate increases toward the main surface of the plate.

[0018] Another aspect of the present invention is a method for manufacturing an annealing plate, which is a method for manufacturing one of a plurality of plates that are to be used in an annealing process for annealing a plate-shaped blank and are to be stacked to hold the blank from both sides,

in which the plate includes:

a pair of main surfaces, at least one of the main surfaces coming into contact with the blank, and

one or more through-holes that are open in the main surfaces and pass through the plate,

the manufacturing method including a forming process for forming a powder raw material of the plate with which a forming mold is filled,

in which the forming mold has a protruding portion that protrudes from an inner wall surface of the forming mold such that the through-hole is formed in the plate.

[0019] Another aspect of the present invention is a method for manufacturing a substrate, the method including:

an annealing process for annealing a plate-shaped blank by heating a stack body in which at least two of the annealing plates or the annealing plates manufactured using the method for manufacturing an annealing plate are stacked to hold the blank from both sides.

[Advantageous Effects of the Invention]

[0020] According to the present invention, it is possible to easily separate annealing plates and blanks that are stacked on each other.

[Brief Description of Drawings]

[0021] FIG. 1 is an external perspective view showing an example of an annealing plate.

FIG. 2 is a cross-sectional view showing an outer circumferential shape of the plate.

FIGS. 3(a) and 3(b) are diagrams showing states in which the plate is removed from a stacked body.

FIGS. 4(a) to 4(d) are diagrams illustrating the flow of air passing through through-holes.

FIGS. 5(a) to 5(c) are diagrams illustrating another example of the flow of air passing through through-holes.

FIG. 6 is a diagram showing a jig for loading and unloading a plate from a stacked body.

FIG. 7 is a diagram showing a cross-section of the plate near a through-hole.

FIG. 8 is a diagram showing a variation of the plate.

FIG. 9 is a diagram showing another variation of the plate.

FIG. 10 is a diagram illustrating an annealing process, using the plate shown in FIG. 1.

[Description of Embodiments]

[0022] The following describes an annealing plate, a method for manufacturing an annealing plate, and a method for manufacturing a magnetic-disk substrate according to an embodiment of the present invention in detail.

[0023] (Annealing plate)

An annealing plate (referred to as a “plate” hereinafter) of this embodiment will be described. This embodiment includes various embodiments, which will be described later.

FIG. 1 shows a plate 10 in this embodiment.

The plate 10 is one of a plurality of plates that are to be used in an annealing process for annealing a glass blank, which is an example of a blank. When an annealing process is performed, the plates 10 are stacked to hold a

plate-shaped glass blank from both sides.

[0024] The plate 10 has a pair of main surfaces 1a and 1b, at least one of the main surfaces coming into contact with the glass blank. The main surfaces 1a and 1b of the plate 10 are substantially circular. In this specification, a "substantially circular shape" includes a perfectly circular shape and an elliptical shape, and the outer circumferential shape thereof may be constituted by an arc having a single radius of curvature, or a plurality of arcs having different radii of curvature.

[0025] The diameter of the plate 10 is 1.05 to 1.5 times the diameter of a glass blank, for example. Here, if the diameter of the plate 10 is smaller than the diameter of a glass blank, there are cases where, while an annealing process is performed, an outer circumferential portion of the glass blank stacked on the plate 10 deforms along an outer circumferential side edge surface of the plate 10, the outer shape of the plate 10 is transferred to a glass blank 20, and thus a mark (transfer mark) forms on a main surface of the glass blank, resulting in deterioration in the flatness of the glass blank. On the other hand, if the diameter of the plate 10 is excessively large, there are cases where the number of stacked bodies that can be disposed in a heating furnace (which will be described later) in an annealing process will decrease and the productivity of glass blanks will decrease. Also, there are cases where the amount of deviation will increase between central positions of a glass blank and the plate 10 when the glass blank and the plate 10 are stacked, the stability will deteriorate due to the center of gravity of the stacked body being biased, and the stacked body will fall or tilt during conveyance. From these viewpoints, it is preferable that the diameter of the plate 10 is 1.05 to 1.2 times the diameter of a glass blank 20.

[0026] It is preferable that the main surfaces 1a and 1b of the plate 10 are larger than main surfaces of the glass blank such that the glass blank staked on the plate 10 does not protrude from the main surfaces 1a and 1b. Accordingly, it is possible to improve the flatness over the entire area of the glass blank, reduce a grinding margin of the glass blank in grinding processing and polishing

processing, or omit grinding processing or polishing processing. Thus, the productivity of magnetic-disk glass substrates will be improved.

[0027] It is preferable that the plate 10 is flatter than a glass blank in order to improve the flatness of the glass blank. The flatness of the plate 10 is 10 μm or less, for example. The flatness is measured using a flatness measuring machine.

[0028] It is preferable that the difference between the coefficient of thermal expansion of the material of the plate 10 and the coefficient of thermal expansion of the material of the glass blank is small. If the difference in the coefficient of thermal expansion between the plate 10 and the glass blank is large, there is a risk that a large amount of stress may be generated in the glass blank in an annealing process due to a difference between the thermal expansion amount and the thermal contraction amount, and may remain on the glass blank after annealing. Thus, it is preferable that a ratio of the coefficient of thermal expansion of the plate 10 to the coefficient of thermal expansion of the glass blank is 0.9 to 1.1 in a temperature range from room temperature to the annealing temperature. The coefficient of thermal expansion refers to the "coefficient of linear expansion" measured through thermomechanical analyses conforming to JIS R1618: 2002. If the material of the glass blank 20 is aluminosilicate glass, the coefficient of thermal expansion of the plate 10 is 3 to 10×10−6/°C in a temperature range of 100°C to 300°C, for example.

[0029] It is preferable that the thermal conductivity of the material of the plate 10 is larger than the thermal conductivity of the material of the glass blank 20. Due to the plate 10 having high thermal conductivity, it is possible to sufficiently transfer heat to the glass blank stacked on the plate 10 in an annealing process. The thermal conductivity refers to a value measured conforming to JIS R1611: 2010. The thermal conductivity of the plate 10 is 1 to 150 W/m・K at room temperature to 300°C, for example.

[0030] Examples of the material of the plate 10 include metal oxides, metal carbides, metal nitrides, metal borides, and materials containing two or more of

them. Specific examples of these materials include alumina (Al_2O_3), silicon carbide (SiC), silicon nitride (Si_3N_4), zirconia (ZrO_2), SiALON ($Si_3N_4 \cdot Al_2O_3$), steatite, spinel, and cordierite. Among them, alumina (Al_2O_3) and silicon carbide (SiC) are preferably used.

[0031] The plate 10 has a thickness of 1 to 3 mm, for example. A specific example of the thickness of the plate 10 is 1.5 mm, for example.

[0032] The shape of an edge surface of the plate 10 may be a shape that linearly extend to be orthogonal to the main surfaces 1a and 1b, or a shape in which end portions orthogonal to the main surfaces 1a and 1b are chamfered. An example of the shape of a chamfered edge surface is a cross-sectional shape shown in FIG. 2, for example. FIG. 2 is a cross-sectional view showing an outer circumferential shape of the plate 10. In the example shown in FIG. 2, the chamfered end portion is curved protruding inward of the plate 10, and a length L1 of the chamfered end portion in a direction parallel to the main surfaces 1a and 1b is 0.2 to 0.4 mm, for example, and is preferably 0.3 mm. A length L2 of the chamfered end portion in a direction (a plate thickness direction) orthogonal to the main surfaces 1a and 1b is 0.05 to 0.2 mm, for example, and is preferably 0.1 mm.

[0033] As shown in FIG. 1, the plate 10 includes one or more through-holes 2 that are open in the main surfaces 1a and 1b and pass through the plate 10. Specifically, the through-holes 2 are open at positions on the main surfaces 1a and 1b such that air flows into a gap between the plate 10 and the glass blank that are stacked. As will be described below, because such through-holes 2 are provided in the plate 10, when the plate 10 is removed from a stacked body 30 (see FIG. 10) after the annealing process, air flows in between the plate 10 and the glass blank 20 (see FIG. 10), inhibiting the glass blank 20 from adhering to the plate 10. From these viewpoints, at least one through-hole 2 is provided such that an edge of the plate 10 that surrounds an opening end of the at least one through-hole 2 is in contact with a main surface of the glass blank 20.

[0034] FIGS. 3(a) and 3(b) are diagrams showing the state in which a plate is

removed from a stacked body, FIG. 3(a) showing a case where a conventional plate 100 is used, and FIG. 3(b) showing a case where the plate 10 according to this embodiment is used.

The conventional plate 100 is provided with no through-holes passing through the plate 100. If the plate 100 is lifted from the annealed stacked body, as shown in FIG. 3(a), a glass blank 20 sticks to a lower surface of the plate 100 and is lifted together with the plate 100. It is conceivable that this is because the pressure of a slight gap between the lower surface of the plate 100 and an upper surface of the glass blank 20 is lower than the pressure (atmospheric pressure) of surrounding portions thereof because the gap tends to spread due to the weight of the glass blank 20. The glass blank 20 sticks thereto in such a manner significantly as the plate 100 is quickly loaded and unloaded to improve the operation efficiency of collecting the glass blank 20.

On the other hand, as shown in FIG. 3(b), because the plate 10 of this embodiment is provided with a through-hole 2, when the plate 10 is lifted, air can flow into the gap located between the plate 10 and the glass blank 20 through the through-hole 2. Thus, the glass blank 20 does not stick to the plate 10, and only the plate 10 is lifted. Because the through-hole 2 is open to an atmosphere in the example shown in FIG. 3(b), when the plate 10 is lifted, air above the plate 10 can flow downward through the through-hole 2. According to this embodiment, it is possible to inhibit the glass blank 20 from sticking to the plate 10, and to easily separate the plate 10 and the glass blank 20 from each other in this manner. Thus, it is possible to efficiently collect the glass blanks 20. Also, it is possible to prevent the glass blank 20 that has stuck to the plate 10 from falling.

[0035] Here, the flow of air through the through-hole 2 will be described with reference to FIG. 4. FIGS. 4(a) to 4(d) show, using arrows, the flow of air through through-holes 2, using, as an example, a stack body in which plates 10A, 10B, and 10C and glass blanks 20A and 20B are placed on a base 60 in an alternating manner. Note that the plates 10A to 10C are each provided with

two through-holes 2. Surface roughness of the main surfaces of the glass blanks 20A and 20B are exaggerated in FIGS. 4(a) to 4(d). In this specification, surface roughness refers to an arithmetic average roughness Ra (JIS B0601: 2001).

Gaps originating from the surface roughness of the plates and the glass blanks are present between the main surfaces of the plates and the main surfaces of the glass blanks that face each other, and these gaps are continuous with the through-holes 2 in the plates. Thus, as shown by double-headed arrows in FIG. 4(a), air can flow between the plate 10A and the glass blank 20A. Here, when the plate 10A is lifted, air can flow into a gap between the plate 10A and the glass blank 20A through the through-holes 2, from above the plate 10A. Note that, at this time, the flow of air into the through-holes 2 through the gap between the plate 10A and the glass blank 20A from the side of the glass blank 20A is also formed. As a result of air flowing between the plate 10A and the glass blank 20A in this manner when the plate 10A is lifted, it is possible to inhibit the glass blank 20A from sticking to the plate 10A.

[0036] Also, the through-holes 2 in the plate 10B are continuous with a gap located between the glass blank 20A and the plate 10B, and a gap located between the glass blank 20B and the plate 10B, and thus, as shown by double-headed arrows in FIG. 4(b), air can flow into these gaps in a state in which the plate 10A is removed from the stacked body. Thus, when the glass blank 20A is lifted, the plate 10B does not stick to the glass blank 20A, and the glass blank 20A can be removed therefrom.

Also, because air can flow as shown by double-headed arrows in FIG. 4(c) in a state in which the glass blank 20A is removed from the stacked body, the glass blank 20B is inhibited from sticking to the plate 10B when the plate 10B is lifted.

[0037] Note that, although the through-holes 2 in the plate 10C are continuous with a gap located between the glass blank 20B and the plate 10C, if there is no gap between the plate 10C and the base 60, no flow of air through this gap and

the through-holes 2 is formed. Thus, it is preferable to take measures as shown in FIGS. 5(a) to 5(c) such that air can flow between the plate 10C and the base 60 located at the bottom of the stacked body.

In the example shown in FIG. 5(a), the surface roughness of a main surface of the plate 10C located on the base 60 side is large, and a gap is present between the plate 10C and the base 60, and thus air can flow as indicated by double-headed arrows shown in FIG. 5(a). Therefore, when the glass blank 20B is lifted, the plate 10C does not stick to the glass blank 20B, and the glass blank 20B can be removed therefrom.

In the example shown in FIG. 5(b), the surface roughness of the surface of the base 60 is large, and a gap is present between the plate 10C and the base 60, and thus air can flow as indicated by double-headed arrows shown in FIG. 5(b). Therefore, when the glass blank 20B is lifted, the plate 10C does not stick to the glass blank 20B, and the glass blank 20B can be removed therefrom.

In the example shown in FIG. 5(c), a hollow region S is formed in a portion that includes the surface of the base 60. The hollow region S is continuous with the through-holes 2 in the plate 10C, and also is continuous with a space located on the outer circumferential side of the plate 10C. Thus, air can flow as shown by double-headed arrows in FIG. 5(c). Therefore, when the glass blank 20B is lifted, the plate 10C does not stick to the glass blank 20B, and the glass blank 20B can be removed therefrom.

[0038] Air flowing through the above-described gaps and through-holes 2 is not limited to air in an atmosphere that is continuous with the gaps and the through-holes 2, and may be air supplied from the outside, separately from the atmosphere. Such air can be supplied using a jig 50 (see FIG. 6) for loading and unloading the plate 10, for example. FIG. 6 is a diagram showing the jig 50 for removing the plates 10 and the glass blanks from a stacked body. The jig 50 includes suction cups 51 and a suctioning mechanism (not shown), and can convey the plate 10 while the suction cups 51 suction the main surface of the plate 10. Also, the jig 50 includes a supply mechanism (not shown) for

supplying air to the through-holes 2. As a result of air being supplied from the jig 50 to the through-holes 2, air flows through the through-holes 2 in between the plate 10 and the glass blank 20 that is in contact with the plate 10, and thus, when the suctioned plate 10 is lifted, it is possible to inhibit the glass blank 20 from sticking to the plate 10, and to easily separate the plate 10 and the glass blank 20 from each other.

[0039] According to an embodiment, it is preferable that the sum of an arithmetic average roughness Ra1 of a main surface of the plate 10 and an arithmetic average roughness Ra2 of a main surface of the glass blank 20 that is in contact with the main surface of the plate 10 is 0.2 μm or more. If the sum of arithmetic average roughnesses is 0.2 μm or more, air can flow into gaps between the plate 10 and the glass blank 20 through the through-holes 2 because sufficient gaps are ensured between the plate 10 and glass blank 20 that are stacked, thus inhibiting the glass blank 20 from sticking to the plate 10. Note that the arithmetic average roughness Ra is measured through stylus-type roughness tester (stylus-type roughness measuring device) with use of a stylus.

In this embodiment, and according to an embodiment, it is preferable that Ra1>Ra2 is satisfied. The effect of inhibiting the glass blank 20 from sticking to the plate 10 is increased by satisfying such a relationship.

[0040] According to an embodiment, it is preferable that the arithmetic average roughness Ra1 of a main surface of the plate 10 is 0.2 to 1.0 μm. If Ra1 is less than 0.2 μm, air is unlikely to pass through between the plate 10 and the glass blank 20, and the glass blank 20 is likely to stick to the plate 10, and thus it takes time to detach the glass blank 20 from the plate 10, and operation efficiency is likely to decrease. Also, if Ra1 is less than 0.2 μm, manufacturing costs of the plate 10 for reducing arithmetic average roughness increase. On the other hand, if Ra1 exceeds 1.0 μm, there is a risk that microparticles will detach from the plate 10 through contact between the glass blank 20 and the plate 10, resulting in the generation of dust. Microparticles detached from the

plate adhere to the surface of the glass blank 20, contaminate the glass blank 20, and scratch the surface of the glass blank 20 in some cases. Also, if Ra1 exceeds 1.0 μm, in particular, if Ra1 is 1.3 μm or more, a special process for increasing an arithmetic average roughness is required, which increases the manufacturing costs of the plate 10. A preferred arithmetic average roughness Ra1 of a main surface of the plate 10 is 0.6 μm, for example.

[0041] An arithmetic average roughness Ra2 of the main surface of the glass blank 20 is 0.001 to 1.3 μm, for example. A preferred example of the arithmetic average roughness Ra2 is 0.7 μm.

[0042] According to an embodiment, it is preferable that the shape of a through-hole 2 that is open in the main surfaces 1a and 1b of the plate 10 is a circular shape, and the through-hole 2 has a diameter of 1 to 6 mm. If the diameter of the through-hole 2 exceeds 6 mm, there are cases where the glass blank 20 stacked on the plate 10 deforms and slightly enters the through-hole 2 while the annealing process is performed, the opening shape of the through-hole 2 is transferred to the glass blank 20, and a mark thereof (transfer mark) forms on a main surface of the glass blank 20. Thus, the flatness of the glass blank 20 may deteriorate in some cases. The glass blank 20 with such a mark is likely to be unsuitable as a base plate of a magnetic-disk glass substrate. Also, if the diameter of the through-hole 2 is less than 1 mm, air is unlikely to flow in between the plate 10 and the glass blank 20, and the flow of air is likely to deteriorate. Thus, there is a risk that it will take time to separate the glass blank 20 from the plate 10, and thus operation efficiency will decrease. Also, if the diameter of the through-hole 2 is less than 1 mm, the manufacturing costs of the through-hole 2 increases. The through-hole 2 more preferably has a diameter of 2 to 5 mm.

[0043] According to an embodiment, the position at which a circular hole is formed (a circular hole formation position) is set in the glass blank 20. The circular hole is a circular hole that is concentric with the outer circumference of the glass blank 20, for example. In this case, it is preferable that the through-

hole 2 is provided in a region of the main surfaces 1a and 1b of the plate 10 that is in contact with a portion of the glass blank 20 in which the circular hole formation position is set. If the through-hole 2 is provided in such a region, even if a transfer mark forms on the glass blank 20, the transfer mark formed on the glass blank 20 has no effects because the transfer mark is removed from the glass blank 20. Note that the circular hole formation position is set in a portion including the center of the main surfaces of the glass blank 20.

[0044] According to an embodiment, as shown in FIG. 7, a side wall 3 of the plate 10 that surrounds the through-hole 2 is preferably chamfered such that the cross-sectional area of the through-hole 2 that extends along a direction that is parallel to the main surface 1a or 1b of the plate 10 (the right-left direction in FIG. 7) increases toward the main surface 1a or 1b of the plate 10. FIG. 7 is a diagram showing a cross-section of the plate 10 near the through-hole 2. In the example shown in FIG. 7, a portion of the chamfered side wall 3 of the plate 10 has inclined wall surfaces 3a that are inclined with respect to the plate thickness direction of the plate 10. Because the side wall 3 of the plate 10 is chamfered, if the glass blank 20 deforms such that the above-described transfer mark forms in the annealing process, it is possible to reduce the amount of deformation thereof, and to suppress the deterioration of the flatness of the glass blank 20. Such inclined wall surfaces 3a are effective in a case where a through-hole 2 is provided in regions of the main surfaces 1a and 1b of the plate 10 that are in contact with portions of the glass blanks 20 other than the circular hole formation positions. An inclination angle of the inclined wall surface 3a with respect to a direction in which the wall surface (the wall surface between the inclined wall surfaces 3a on both sides) of the side wall 3 other than the inclined wall surface 3a extends is preferably 30 to 60 degrees, and is, for example, 45 degrees. Note that the cross-sectional shape of a portion of the chamfered side wall 3 of the plate 10 is not limited to a linear shape such as that shown in FIG. 7, and may be bent or curved in a shape protruding or recessed inward of the through-hole 2.

[0045] According to an embodiment, it is preferable that a plurality of the through-holes 2 are provided, and are dispersed and are open in the main surfaces 1a and 1b. Accordingly, the effects of inhibiting the glass blank 20 from sticking to the plate 10 increase. The number of through-holes 2 is one, two, three, four, five, or more, for example.

As shown in FIG. 8, with regard to a plurality of through-holes 2, when the main surfaces 1a and 1b of the plate 10 are divided into a plurality of regions having equal areas, the same number of through-holes 2 are preferably arranged in the respective regions, and, for example, one through-hole 2 is preferably arranged in each region. FIG. 8 is a diagram showing a variation of the plate 10. In the example shown in FIG. 8, the main surfaces 1a and 1b are each divided into four regions by two virtual lines (broken lines) that are orthogonal to each other at the center of the main surfaces 1a and 1b of the plate 10, and one through-hole 2 is arranged in each region.

On the other hand, if the number of through-holes 2 increases, a transfer mark is likely to form on the glass blank 20. Thus, the preferred number of through-holes 2 provided in the plate 10 is 1 to 4. Also, in this embodiment, as described above, it is also preferable to provide the through-hole 2 in regions of the main surfaces 1a and 1b that is in contact with a portion of the glass blank 20 in which a circular hole formation position is set. Also, it is preferable to reduce the opening areas of the through-holes 2, or to reduce the total opening areas of the through-holes 2.

[0046] The opening shape of a through-hole 2 in the plate 10 is not limited to a substantially circular shape, and may be a polygonal shape, a shape extending in one or more directions in which the plate 10 extends, or the like. As shown in FIG. 9, examples of the shape extending in one direction include a shape extending along a circumferential direction of the plate 10. FIG. 9 is a diagram showing another variation of the plate 10. Also, examples of the shape extending in a plurality of directions include a shape extending in three or more directions (e.g., a Y-shape, a cross-shape).

Also, the direction in which the through-hole 2 extends is not limited to a direction parallel to the plate thickness direction, and may also be a direction inclined with respect to the plate thickness direction. Also, the through-hole 2 may be curved or bent and extend between portions on both sides in the extending direction of the through-hole 2.

[0047] The above-described plate 10 can also be used in an annealing process for annealing a blank other than a glass blank, such as an aluminum blank.

[0048] (Method for manufacturing plate)

Next, a method for manufacturing a plate according to this embodiment will be described below. This embodiment includes various embodiments, which will be described later.

The method for manufacturing a plate is a method for manufacturing one of a plurality of plates that are to be used in an annealing process for annealing a glass blank and that are to be stacked to hold a plate-shaped glass blank from both sides.

This plate has a pair of main surfaces, at least one of the main surfaces coming into contact with a glass blank, and the plate includes one or more through-holes that are open in the main surfaces and pass through the plate. That is, the plate is similar to the above-described plate 10.

This manufacturing method includes a forming process for forming a powder raw material of the plate with which a forming mold is filled.

The forming mold has a protruding portion that protrudes from an inner wall surface of the forming mold such that the through-hole is formed in the plate.

According to this manufacturing method, it is possible to produce a plate provided with through-holes through the forming process, and to produce a plate at lower costs than in a case where a through-hole is provided by punching through a base plate for the plate that has no through-holes. A plate made of the above-described metal compound material is hard, for example, and it is costly to form a hole with use of a tool such as a drill, or laser.

[0049] In the forming process, it is possible to perform degreasing and sintering after the forming process is performed through cold isostatic pressing (CIP), for example. Although sintering may be performed through atmospheric pressure sintering, it is preferable to press and solidify through gas pressure sintering, or hot isostatic pressing (HIP) after sintering.

It is also possible to manufacture a plate that is to be used in an annealing process for annealing a blank other than a glass blank, such as an aluminum blank, using the above-described method for manufacturing a plate.

[0050] (Magnetic-disk substrate)

Next, a magnetic-disk substrate according to this embodiment will be described below. Note that this embodiment is suitable for manufacturing a magnetic-disk glass substrate having a nominal size of 2.5 to 3.5 inches (having a diameter of 65 to 95 mm), and having a substrate thickness of 0.1 to 1.5 mm, or preferably having a substrate thickness of 0.3 to 0.9 mm.

The magnetic-disk glass substrate has a circular plate shape. Note that a central hole having a circular shape concentric with the outer circumference of a magnetic-disk glass substrate is hollowed out so that the magnetic-disk glass substrate has a ring shape. A magnetic disk is formed by forming magnetic layers (recording regions) in annular regions of both surfaces of the magnetic-disk glass substrate.

[0051] (Blank for magnetic disk)

A glass blank for a magnetic disk (simply referred to as a “glass blank” hereinafter), which is an example of a blank for a magnetic disk, is a glass plate that is produced through press-molding processing, and has not undergone grinding processing, which will be described later. Note that a glass blank is not limited to a blank produced through press-molding processing, and may be produced using a float method, a fusion method, or the like. The shape of a glass blank is a substantially circular shape. Also, a glass blank may have a circular hole formed through circular hole formation processing, which will be described later.

Aluminosilicate glass, soda-lime glass, borosilicate glass, and the like can be used as the material of the glass blank. In particular, aluminosilicate glass can be suitably used in light of the fact that it is possible to perform chemical strengthening and to produce a magnetic-disk glass substrate that has good flatness of main surfaces and high substrate strength.

[0052] (Method for manufacturing magnetic-disk substrate)

Next, a method for manufacturing a magnetic-disk substrate according to this embodiment will be described below. This embodiment includes various embodiments, which will be described later.

First, a glass blank is produced by press-molding a molten glass mass, which is a raw material of a plate-shaped magnetic-disk glass substrate having a pair of main surfaces (press-molding processing). Then, heat treatment for eliminating warping of the glass blank is performed (annealing process). After the annealing process, a circular hole is formed in a central portion of the glass blank, and the resulting glass blank has a ring shape (annular shape) (circular hole formation processing).

Then, shape processing is performed on the glass blank through edge surface grinding (shape processing). Accordingly, a glass substrate having a ring shape (an annular shape) is produced. Then, main surface grinding (grinding processing) is performed using fixed abrasive particles, and edge surface polishing is performed on a flat glass substrate (edge surface polishing processing). Then, first polishing is performed on main surfaces of the glass substrate (first polishing processing). Then, chemical strengthening is performed on the glass substrate as needed (chemical strengthening processing). Then, second polishing is performed on the chemically strengthened glass substrate (second polishing processing). A magnetic-disk glass substrate can be obtained through the above-described processing. Hereinafter, each process will be described in detail.

[0053] (a) Press-molding processing

A glass blank is molded by cutting a molten glass flow using a cutter,

and pressing the mass of the cut molten glass held between pressing surfaces of a pair of molds. In this embodiment, as will be described later, after a leading end portion of the molten glass flow is dropped on an upper surface of a lower mold, the mass of molten glass is obtained by cutting the molten glass flow at a position on the upstream side, and a glass blank is molded by pressing downward the mass of molten glass from above with use of an upper mold.

After pressing is performed for a predetermined time period, the molds are opened to remove the glass blank.

[0054] (b) Annealing process

In the annealing process, a glass blank is annealed by heating a stacked body obtained by stacking a plurality of plates to hold the glass blank from both sides thereof. The above-described plate 10 is used as the plate. Specifically, the stacked body is constituted by stacking the plates 10 and the glass blanks 20 in an alternating manner as shown in FIG. 10. The number of plates 10 is one more than the number of glass blanks 20 (e.g., 10 to 30), and the plates 10 are disposed at positions including the uppermost position and the lowermost position of the stacked body 30. An annealing process is performed by applying a load to the uppermost layer of the stacked body 30 and keeping the temperature inside the heating furnace 40.

[0055] (c) Circular hole formation processing

A disk-shaped glass blank provided with a circular hole is obtained by forming a circular hole (a circular hole) in the glass blank through coring, scribing, or the like.

[0056] Coring is a method in which a circumferential portion of the circular hole is cut and glass of the central portion (core) is hollowed out by cutting one of the main surfaces of the glass blank using a tubular core drill having one open end, and thus a through-hole is formed. Note that the circumferential portion (inner circle) of the circular hole is cut and the glass blank may be cut along a circular cutting line (outer circle), which is an outer contour of the glass blank, using a core drill. Thereafter, a disk-shaped glass blank can be obtained by

removing a portion located outside the outer circle of the glass blank and a portion located inside the inner circle.

[0057] Scribing is a method in which one main surface of a glass blank is provided with a circular cutting line with use of a cutter (scriber) made of a super steel alloy or diamond particles, the circular cutting line is then extended in the thickness direction of the glass blank by heating the glass blank, and then an inner portion of the circular cutting line is pressed and separated. Note that a circular cutting line serving as a contour of the circular hole and a circular cutting line serving as an outer contour of the glass blank may be formed simultaneously. In this case, the circular cutting line serving as the outer contour of the glass blank (outer circle) and the circular cutting line serving as the contour of the circular hole (inner circle) are formed so as to be concentric with each other. Thereafter, by partially heating the glass blank, due to a difference in the thermal expansion of the glass blank, the portion located outside the outer circle of the glass blank and the portion located inside the inner circle are removed, and a disk-shaped glass blank can be obtained.

[0058] (d) Shape processing

In the shape processing, chamfering processing is performed on an outer circumferential edge portion of the glass blank. If a circular hole is formed in the glass blank, chamfering processing is also performed on an inner circumferential edge portion of the circular hole.

[0059] (e) Grinding processing

In the grinding processing, grinding processing is performed on the main surfaces of the glass blank, using a double-side grinding apparatus provided with a planetary gear mechanism. Specifically, two main surfaces of the glass blank are ground while the outer circumferential side edge surface of the glass blank is held in a holding hole provided in a holding member of the double-side grinding apparatus. The double-side grinding apparatus has a pair of upper and lower surface plates (an upper surface plate and a lower surface plate), and the glass substrate is held between the upper surface plate and the lower surface

plate. The glass blank and the surface plates are moved relative to each other by moving one or both of the upper surface plate and the lower surface plate, and thereby the two main surfaces of the glass blank can be ground. Accordingly, it is possible to adjust the plate thickness and improve flatness.

[0060] (f) Edge surface polishing processing

In the edge surface polishing processing, mirror finishing is performed by brushing the outer circumferential side edge surface of the glass substrate obtained through processing for grinding glass blank. If a circular hole is formed in the glass substrate, mirror-finishing is also performed on an inner circumferential side edge surface of the circular hole. At this time, an abrasive particle slurry containing cerium oxide microparticles or the like as loose abrasive particles is used.

[0061] (g) First polishing processing

First polishing processing is performed in order to eliminate blemishes and warping and adjust minute unevenness (microwaviness, roughness) remaining on the main surfaces in the case where grinding with fixed abrasive particles is performed, for example. Specifically, the main surfaces on both sides of the glass substrate are polished while the outer circumferential side edge surface of the glass substrate is held in a holding hole provided in a carrier for polishing of the double-side polishing apparatus.

[0062] In the first polishing processing, the glass substrate is polished using a double-side polishing apparatus including a configuration similar to that of the double-side grinding apparatus that is used in grinding processing with fixed abrasive particles, while a polishing slurry is provided. In the first polishing processing, unlike grinding with fixed abrasive particles, a polishing slurry containing loose abrasive particles is used, instead of fixed abrasive particles.

[0063] Similarly to the double-side grinding apparatus, the double-side polishing apparatus has a pair of upper and lower surface plates (an upper surface plate and a lower surface plate), and the glass substrate is held between the upper surface plate and the lower surface plate. Tabular polishing pads

(resin polishers, for example) having an annular shape overall are attached to the upper surface of the lower surface plate and the bottom surface of the upper surface plate. The glass substrate and the surface plates are moved relative to each other by moving one or both of the upper surface plate and the lower surface plate, and thereby the two main surfaces of the glass substrate are polished.

[0064] Note that the glass substrate may be chemically strengthened by immersing the glass substrate that has undergone the first polishing processing in a chemical strengthening liquid (chemical strengthening processing). A melt in which potassium nitrate and sodium nitrate are mixed, for example, can be used as the chemical strengthening liquid.

[0065] (h) Second polishing (final polishing) processing

The second polishing processing is performed in order to mirror-polish the main surfaces. A double-side polishing apparatus having a configuration that is similar to that of the double-side polishing apparatus that is used in first polishing is used in second polishing as well. Specifically, main surfaces on both sides of the glass substrate are polished while the outer circumferential side edge surface of the glass substrate is held in a holding hole provided in a carrier for polishing of the double-side polishing apparatus. The second polishing processing differs from the first polishing processing in that the type and particle size of loose abrasive particles are different, and the hardness of the resin polishers is different. Specifically, a polishing liquid containing colloidal silica having a particle size of about 5 to 100 nm as the loose abrasive particles is supplied between the polishing pads of the double-side polishing apparatus and the main surfaces of the glass substrate, and the main surfaces of the glass substrate are polished. The polished glass substrate is cleaned using a neutral detergent, pure water, isopropyl alcohol, or the like, and thereby a magnetic-disk glass substrate can be obtained.

[0066] With the method for manufacturing a magnetic-disk glass substrate according to this embodiment, it is possible to easily separate the plates 10 and

the glass blanks 20 after an annealing process, and to efficiently collect the glass blanks 20 because the annealing process is performed using the plates 10 provided with the through-holes 2. Thus, the productivity of the magnetic-disk glass substrates is also improved. Also, it is possible to prevent the glass blank 20 from dropping when removing the plate 10 after the annealing process. Accordingly, it is possible to inhibit the glass blank 20 from being inappropriate as a base plate of a magnetic-disk glass substrate, and to inhibit a decrease in the yield of magnetic-disk glass substrates.

[0067] It is also possible to manufacture a substrate other than a magnetic-disk glass substrate, such as an aluminum substrate for a magnetic disk, using the above-described method for manufacturing a substrate.

[0068] (Experimental Example)

In order to examine the effects of a plate according to this embodiment, an annealing process was performed using plates and glass blanks with various specifications.

The annealing processing was performed by assembling a stacked body made of a combination of plates and glass blanks with specifications shown in Tables 1 to 3 below. With regard to each sample, a stacked body was assembled by disposing, on a base, 61 plates having the same specification and 60 glass blanks having the same specification one-by-one in an alternating manner, a 500 g weight was placed on the uppermost plate, and an annealing process was performed in the heating furnace 40 shown in FIG. 10 under the heat retention conditions at 500°C to 550°C for 30 to 120 minutes. Note that the plate that was disposed in the lowermost layer and the base had the forms shown in FIG. 5(b).

[0069] A substantially circular plate that had a diameter of 110 mm and was made of alumina was used as the plates of Samples 1 to 25.

The position of a through-hole in a main surface of the plate was located on the inner side of a circle that was concentric with the outer circumference of the plate and whose diameter was half of the diameter of the plate. The

through-hole had a shape extending in a round tubular shape in the plate thickness direction.

A substantially circular glass blank that had a diameter of 100 mm and was made of aluminosilicate glass was used as the glass blank. Also, a glass blank that was produced using a float method was used as the glass blanks of Samples 21 to 23, and a glass blank that was produced through press-molding processing was used as the glass blanks of samples other than Samples 21 to 23.

[0070] After the annealing process, the number of instances of sticking, the number of transfer marks, and the number of contaminated glass blanks were counted in the following manner.

(1) Number of instances of sticking

A sample in which, when plates were loaded and unloaded one-by-one from the uppermost position, the number of instances of stacking of a glass blank was less than three out of 60 glass blanks was evaluated as A, a sample in which the number thereof was three or more and was less than 10 was evaluated as B, a sample in which the number thereof was 10 or more was evaluated as C, and A and B were evaluated as sticking being inhibited, and C was evaluated as sticking not being inhibited. A plate was loaded and unloaded in a time period that was half of a time period that is usually required.

(2) Number of transfer marks

A sample in which, when main surfaces on both sides of 60 glass blanks were visually observed, the number of glass blanks that had transfer marks originating from a through-hole was less than three out of 60 glass blanks was evaluated as A+, a sample in which the number thereof was three or more and was less than five was evaluated as A, a sample in which the number thereof was five or more and was less than 10 was evaluated as B, a sample in which the number thereof was 10 or more and was less than 15 was evaluated as C, and a sample in which the number thereof was 15 or more was evaluated as D, and A+ to C were evaluated as transfer marks being inhibited, and D was evaluated as transfer marks not being inhibited.

(3) Number of contaminated glass blanks

Main surfaces on both sides and edge surfaces of 60 glass blanks were observed using a slanting incidence interference method flatness tester (FT-17 manufactured by NIDEK CO., LTD.). A sample in which the number of glass blanks to which particles that were generated from a plate and had a size of 1 to 100 μm were attached was less than five out of 60 glass blanks was evaluated as A, a sample in which the number thereof was five or more and was less than 10 was evaluated as B, and a sample in which the number thereof was 10 or more was evaluated as C, and A and B were evaluated as the contamination of glass blanks being inhibited, and C was evaluated as the contamination of glass blanks not being inhibited.

Results are shown in Tables 1 to 3.

[0071] [Table 1]

Sample No.	1	2	3	4	5
Number of through-holes	0	0	0	0	0
Ra1 of plate(μm)	1.5	1.5	1	0.6	0.2
Ra2 of blank (μm)	0.7	0.001	0.7	0.7	0.7
Ra1+Ra2 (μm)	2.2	1.501	1.7	1.3	0.9
Number of instances of sticking	A	B	B	C	C
Number of contaminated glass blanks	C	C	B	A	A

[0072] [Table 2]

Sample No.	6	7	8	9	10	11	12	13	14	15
Number of through-holes	1	1	4	1	4	1	1	4	1	4
Diameter of hole (mm)	1	6	6	10	10	1	6	6	10	10
Ra1 of plate (μm)	0.6	0.6	0.6	0.6	0.6	0.2	0.2	0.2	0.2	0.2
Ra2 of blank (μm)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Ra1+Ra2 (μm)	1.3	1.3	1.3	1.3	1.3	0.9	0.9	0.9	0.9	0.9
Number of instances of sticking	A	A	A	A	A	A	A	A	A	A
Number of transfer marks	A+	A	B	B	B	A+	A	B	B	C
Number of contaminated glass	A	A	A	A	A	A	A	A	A	A

blanks										

[0073] [Table 3]

Sample No.	16	17	18	19	20	21	22	23	24	25
Number of through-holes	1	1	4	1	4	1	1	4	1	1
Diameter of hole (mm)	1	6	6	10	10	6	6	6	6	6
Ra1 of plate (μm)	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.001	0.001	0.001
Ra2 of blank (μm)	0.2	0.2	0.2	0.2	0.2	0.001	0.001	0.001	0.2	0.1
Ra1+Ra2 (μm)	0.4	0.4	0.4	0.4	0.4	0.201	0.101	0.002	0.201	0.101
Number of instances of sticking	A	A	A	A	A	A	C	C	B	C
Number of transfer marks	A+	A	B	B	C	A+	A	B	B	B
Number of contaminated glass blanks	A	A	A	A	A	A	A	A	A	A

[0074] From the comparison between Samples 6 to 25 and Samples 1 to 5, it can be understood that sticking can be inhibited due to a plate having a through-hole. Note that, when experiments were conducted under the same conditions except that, with regard to Samples 22, 23, and 25, it took about twice the amount of time (normally required time) to load and unload plates, the evaluation of the number of instances of sticking was B, and it was found that sticking was inhibited. On the other hand, when experiments were conducted under the same conditions except that, with regard to Samples 4 and 5, it took about twice the amount of time to load and unload plates, the evaluation of the number of instances of sticking was C, and it was found that sticking was not able to be inhibited.

[0075] As can be understood from the results of Samples 6 to 10, the smaller the number of through-holes is and the smaller the diameter of a through-hole is, the greater the transfer mark inhibition effect is. In particular, it was found that, if the number of through-holes is two or less, or if the diameter of a through-hole is 6 mm or less, the transfer mark inhibition effect is particularly

significant. Also, the results of Samples 11 to 15 and the results of Samples 16 to 20 reveal the same thing.

[0076] Note that it was found through comparisons between Samples 1 to 3 and Samples 4 and 5 that, when main surfaces of a plate have a small arithmetic average roughness Ra1, the number of contaminated glass blanks can be reduced.

[0077] When an annealing process was performed on Samples 9, 14, and 19 by respectively changing the diameters of plates to 95 mm, 95 mm, and 90 mm, transfer marks originating from outer circumferential edges of plates were formed on 15 or more out of 60 glass blanks in all the samples.

[0078] As described above, although an annealing plate, a method for manufacturing an annealing plate, and a method for manufacturing a substrate according to the present invention have been described in detail, the present invention is not limited to the above-described embodiments, and it will be appreciated that various improvements and modifications can be made without departing from the gist of the present invention.

[List of Reference Numerals]

[0079] 1a, 1b Main surface
2 Through-hole
3 Side wall
3a Inclined wall surface
10, 10A, 10B, 10C Annealing plate
20, 20a, 20B Glass blank
30 Stacked body
40 Heating furnace
50 Jig
60 Base

CLAIMS

1. An annealing plate, which is one of a plurality of plates that are to be used in an annealing process for annealing a plate-shaped blank and are to be stacked to hold the blank from both sides,

the annealing plate comprising a pair of main surfaces, at least one of the main surfaces coming into contact with the blank~~; and~~,

one or more through-holes that are open in the main surfaces and pass through the plate~~.~~,

the main surface has an arithmetic average roughness that is adjusted such that air flows into gaps between the plate and the blank that are stacked,

the gaps are continuous with through-holes,

a position at which a circular hole is to be formed is set in the blank, and

the through-hole is open in a region of the main surface of the plate that comes into contact with a portion of the blank in which the position is set.

~~2. The annealing plate according to claim 1,~~

~~wherein the main surface has an arithmetic average roughness that is adjusted such that air flows in between the plate and the blank that are stacked.~~

~~3~~2. The annealing plate according to claim 1~~ or 2~~,

wherein a sum of arithmetic average roughnesses of the main surface of the plate and a main surface of the blank that comes into contact with the main surface is 0.2 μm or more.

~~4~~3. The annealing plate according to ~~any one of~~ claim~~s~~ 1 or 2~~to 3~~,

wherein an arithmetic average roughness of the main surface of the plate is larger than an arithmetic average roughness of a main surface of the blank that comes into contact with the main surface.

~~5~~4. The annealing plate according to any one of claims 1 to ~~4~~3,

wherein an arithmetic average roughness of the main surface of the plate is 0.2 to 1.0 μm.

~~6~~5. The annealing plate according to any one of claims 1 to ~~5~~4,

wherein at least one of the through-holes is open in the main surface of the plate such that an edge of the plate surrounding the at least one through-hole comes into contact with a main surface of the blank.

~~7~~6. The annealing plate according to any one of claims 1 to ~~6~~5,

wherein a shape of the through-holes that are open in the main surfaces of the plate is a circular shape, and

the through-holes have a diameter of 1 to 6 mm.

~~8~~7. The annealing plate according to any one of claims 1 to ~~7~~6,

wherein a plurality of the through-holes are provided, and are dispersed and are open in the main surfaces of the plate.

~~9~~8. The annealing plate according to claim ~~8~~7,

wherein, when the main surfaces of the plate are divided into a plurality of regions having equal areas, the same number of through-holes are arranged in the respective regions.

~~10~~9. The annealing plate according to any one of claims 1 to ~~9~~8,

wherein a position at which a circular hole is to be formed is set in the blank, and

the through-hole is open in a region of the main surface of the plate that comes into contact with a portion of the blank in which the position is set.

~~11. The annealing plate according to any one of claims 1 to 10,~~

~~wherein a side wall of the plate that surrounds the through-hole is chamfered such that a cross-sectional area of the through-hole extending along a direction that is parallel to the main surface of the plate increases toward the main surface of the plate.~~

~~12~~10. A method for manufacturing one of a plurality of plates that are to be used in an annealing process for annealing a plate-shaped blank and are to be stacked to hold the blank from both sides,

wherein the plate includes

a pair of main surfaces, at least one of the main surfaces coming into contact with the blank, and

one or more through-holes that are open in the main surfaces and pass through the plate,

the manufacturing method comprising a forming process for forming a powder raw material of the plate with which a forming mold is filled,

wherein the forming mold has a protruding portion that protrudes from an inner wall surface of the forming mold such that the through-hole is formed in the plate.

~~13~~11. A method for manufacturing a substrate, comprising

an annealing process for annealing a plate-shaped blank by heating a stack body in which at least two of the annealing plates according to any one of claims 1 to ~~11~~ 9 or the annealing plates manufactured using the manufacturing method according to claim ~~12~~ 10 are stacked to hold the blank from both sides.