

DESCRIPTION

[Title of Invention]

METHOD FOR MANUFACTURING MAGNETIC-DISK GLASS SUBSTRATE

5

[Technical Field]

[0001] The present invention relates to a method for manufacturing a magnetic-disk glass substrate, and specifically, to a method for manufacturing a magnetic-disk glass substrate including a step of polishing an end surface of
10 the glass substrate.

[Background Art]

[0002] Nowadays, personal computers, notebook-type personal computers, digital versatile disc (DVD) recorders, and the like have a built-in hard disk drive (HDD) for data recording. In particular, a magnetic disk in which a
15 magnetic layer is provided on a magnetic-disk glass substrate is used in a hard disk drive that is used in a device premised on portability, such as a notebook-type personal computer. On the surface of the magnetic disk, magnetic recording information is recorded on or read from the magnetic layer of the magnetic disk with a magnetic head (DFH (dynamic flying height) head)
20 that flies slightly above this surface. A glass substrate is unlikely to be plastically deformed compared with a metal substrate and the like, and thus is preferably used as the substrate of magnetic disks.

[0003] Nowadays, the density of magnetic recording has been increased to meet the demand for an increase in the storage capacity of hard disk drives.
25 As a result, the magnetic recording information area has been made smaller by making the flying height of the magnetic head from the magnetic recording surface extremely short. Such a magnetic-disk glass substrate is produced so as to reduce the surface unevenness of the substrate as much as possible.

With a magnetic head that is used in a hard disk drive, known thermal
30 asperity may occur when minute unevenness exists on the surface of the

magnetic disk, possibly causing reproduction to malfunction or disabling reproduction. Raised portions formed on the surface of the magnetic disk due to foreign matter on the glass substrate cause adiabatic compression and adiabatic expansion of air near the head due to the high speed rotation of the magnetic disk, resulting in the magnetic head generating heat, which is the cause of this thermal asperity. That is, thermal asperity can also occur in the case where the magnetic head does not come into contact with the magnetic disk.

[0004] Accordingly, in order to prevent thermal asperity, it is necessary to make the surface of the magnetic disk into an extremely smooth surface that is highly cleaned and void of foreign matter.

[0005] It is thought that the cause of foreign matter attached to the surface of a magnetic-disk glass substrate is not only the surface shape of the glass substrate but also the surface shape of the end surface of the glass substrate.

That is, if the end surface of the magnetic-disk glass substrate does not have a smooth surface shape, this end surface rubs against the wall surface of the resin case, and microparticles (particles) of resin and glass are produced by this rubbing. Such microparticles and microparticles in an atmosphere are trapped on the end surface of the magnetic-disk glass substrate and accumulate. The microparticles accumulating on the end surface of the magnetic-disk glass substrate are a source of dust and cause foreign matter to attach to the surface of a disk substrate in later steps or after the disk is mounted in a hard disk drive. Furthermore, the microparticles accumulating on the end surface of the magnetic-disk glass substrate may attach to a reading element or a recording element of the magnetic head and damage the element. In particular, the microparticles are likely to be trapped on the end surface on the inner circumferential side of the magnetic-disk glass substrate due to the surface shape being rougher than that of the end surface on the outer circumferential side, and it is thought that this hinders high cleaning of the surface of the magnetic-disk glass substrate.

[0006] As disclosed in Patent Literature 1, the end surface of a magnetic-disk glass substrate is generally polished using a brush and a polishing slurry. However, this polishing has a small polishing force and a small processing rate, and therefore, it is difficult to manufacture a large number of magnetic-disk glass substrates in a short time.

On the other hand, a method for polishing a magnetic-disk glass substrate by applying a magnetic field to a slurry containing ferrite-based magnetic particles and polishing abrasive particles is also known (Patent Literature 2).

Specifically, in the method for performing polishing by applying a magnetic field to a slurry, a step of polishing the inner circumferential end surface of a circular hole in the center portion of the glass substrate to be used as a material for the magnetic-disk glass substrate involves forming a magnetic field on the inner circumferential side of the circular hole, holding the slurry by the magnetic field in the circular hole, and moving the magnetic field relative to the end surface on the inner circumferential side of the circular hole, as a result of which the abrasive is moved against the end surface on the inner circumferential side of the circular hole to polish the end surface on the inner circumferential side of the circular hole by a magnetic polishing method.

More specifically, magnets forming a pair are respectively provided on the outer circumferential side of the magnetic-disk glass substrate and on the inner circumferential side of the circular hole, and therefore, the magnetic field lines formed by the pair of magnets extend in the radial direction of the magnetic-disk glass substrate.

[Citation List]

[Patent Literature]

[0007] [Patent Literature 1]: JP H11-28649A

[Patent Literature 2]: JP 2005-50501A

[Summary of Invention]

[Technical Problem]

[0008] However, in the above described method for performing magnetic polishing on a magnetic-disk glass substrate, a pair of magnets are provided on the outer circumferential side as well as the inner circumferential side of the circular hole of the magnetic-disk glass substrate, and therefore, the distance
5 between the inner circumferential end surface to be polished and the magnet provided on the outer circumferential side is large. Therefore, there is a problem in that since the slurry cannot be sufficiently held, the processing rate of polishing is low, and the surface roughness of the end surface on the inner circumferential side to be polished cannot be efficiently reduced. Furthermore,
10 the configuration of the device for magnetic polishing is also complicated regarding the arrangement of the magnets. In addition, magnetic polishing on the end surface on the outer circumferential side of the magnetic-disk glass substrate cannot be simultaneously performed on the end surface on the inner circumferential side.

[0009] Accordingly, it is an object of the present invention to provide a method for manufacturing a magnetic-disk glass substrate that is able to increase the processing rate of polishing above conventional rates and to perform polishing efficiently, when polishing a glass substrate to be used in a magnetic-disk glass substrate.

[Solution to Problem]

[0010] The present invention includes the following aspects.

An aspect of the present invention is a method for manufacturing a magnetic-disk glass substrate.

[0011] [Aspect 1]

25 The method includes a step of performing end surface polishing on a glass substrate, wherein in the step of performing end surface polishing, magnetic field lines that extend in a thickness direction of the glass substrate are formed using a magnetism generating means, a magnetic slurry containing polishing abrasive particles and a magnetic functional fluid is disposed in the
30 magnetic field lines to hold the magnetic slurry along the magnetic field lines,

and an end surface of the glass substrate is brought into contact with the magnetic slurry held by the magnetic field lines, and the end surface and the magnetic slurry are moved relative to each other in the contacting state to polish the end surface of the glass substrate.

5 [0012] [Aspect 2]

In the method for manufacturing a magnetic-disk glass substrate according to aspect 1, the magnetic slurry forms a mass along the magnetic field lines, and the end surface of the glass substrate is pressed against the inside of the mass in a direction orthogonal to the magnetic field lines, and the
10 end surface of the glass substrate is polished.

[0013] [Aspect 3]

In the method for manufacturing a magnetic-disk glass substrate according to aspect 1 or 2, the end surface of the glass substrate include a side wall surface that extends in the direction orthogonal to both main surfaces of
15 the glass substrate and chamfered surfaces that connect the side wall surface and both main surfaces and that are inclined with respect to the main surfaces, and when the end surface of the glass substrate is polished, the side wall surface and the chamfered surfaces are simultaneously polished.

[0014] [Aspect 4]

20 In the method for manufacturing a magnetic-disk glass substrate according to any one of aspects 1 to 3, the magnetism generating means includes a pair of magnets that are disposed in a separated state in the thickness direction of the glass substrate such that a surface on an N-pole side and a surface on an S-pole side are opposed to each other.

25 [0015] [Aspect 5]

In the method for manufacturing a magnetic-disk glass substrate according to any one of aspects 1 to 3, the magnetism generating means includes a pair of magnets that are disposed in a separated state in the thickness direction of the glass substrate such that a surface on an N-pole side
30 and a surface on an S-pole side are opposed to each other, and the end surface

of the glass substrate is pressed against the inside of the magnetic slurry so as to come into contact with a portion inside the magnetic slurry held by the magnetic field lines that connect the N-pole and the S-pole.

[0016] [Aspect 6]

5 In the method for manufacturing a magnetic-disk glass substrate according to any one of aspects 1 to 3, a spacer made of a non-magnetic substance is provided between the surface on the N-pole side and the surface on the S-pole side of the pair of magnets.

[0017] [Aspect 7]

10 In the method for manufacturing a magnetic-disk glass substrate according to any one of aspects 1 to 6, the glass substrate has a disc shape that has a circular through hole having a central point at the center of the glass substrate, the magnetism generating means includes an inner circumferential side means that is provided in the through hole and forms magnetic field lines
15 on the inner circumferential side that extend in the thickness direction of the glass substrate around the end surface on the inner circumferential side that is a side wall surface of the through hole, and the end surface on the inner circumferential side of the glass substrate is brought into contact with the magnetic slurry held by the magnetic field lines on the inner circumferential
20 side formed by the inner circumferential side means, and the end surface and the magnetic slurry are moved relative to each other in the contacting state to polish the end surface on the inner circumferential side.

[0018] [Aspect 8]

 The method for manufacturing a magnetic-disk glass substrate
25 according to aspect 7, the magnetic slurry is formed in an annular shape on a surface of a rotation body that has a central axis and is rotatable about the central axis, and when the end surface on the inner circumferential side of the glass substrate is polished, the magnetic slurry is rotated due to the rotation of the rotation body, and the entire circumference of the end surface on the inner
30 circumferential side of the glass substrate and the entire circumference of the

magnetic slurry are brought into contact and the glass substrate is rotated in an opposite direction to a direction in which the glass substrate is rotated.

[0019] [Aspect 9]

In the method for manufacturing a magnetic-disk glass substrate according to aspect 7 or 8, the magnetism generating means includes an outer circumferential side means that is provided on the outer circumferential side of the glass substrate and forms magnetic field lines on the outer circumferential side that extend in a thickness direction of the glass substrate around the end surface on the outer circumferential side of the glass substrate, and the end surface on the outer circumferential side of the glass substrate is brought into contact with the magnetic slurry held by the magnetic field lines on the outer circumferential side formed by the outer circumferential side means, and the end surface and the magnetic slurry are moved relative to each other in the contacting state to polish both the end surface on the inner circumferential side and the end surface on the outer circumferential side.

[0020] [Aspect 10]

The method for manufacturing a magnetic-disk glass substrate is a method for manufacturing a plurality of magnetic-disk glass substrate including a step of stacking a plurality of glass substrates to form a stack of glass substrates, and performing end surface polishing on each of the glass substrates in the stack, wherein in the step of performing end surface polishing, magnetic field lines that extend in a stacking direction of the stack are formed at a plurality of positions using a magnetism generating means, a magnetic slurry containing polishing abrasive particles and a magnetic functional fluid is disposed at the plurality of positions to hold the magnetic slurry along the magnetic field lines, and at each of the plurality of positions, an end surface of each glass substrate in the stack is brought into contact with the magnetic slurry held by the magnetic field lines, and the end surface and the magnetic slurry are moved relative to each other in the contacting state to polish the end surface of each glass substrate in the stack.

[0021] [Aspect 11]

In the method for manufacturing a magnetic-disk glass substrate according to aspect 10, the magnetism generating means includes a plurality of pairs of magnets that are disposed in a separated state in a stacking direction
 5 of the stack such that a surface on an N-pole side and a surface on an S-pole side are opposed to each other, and the plurality of magnets are provided at a plurality of positions in the stacking direction of the stack.

[0022] [Aspect 12]

In the method for manufacturing a magnetic-disk glass substrate
 10 according to aspect 10 or 11, a spacer made of a non-magnetic substance is provided between the surface on the N-pole side and the surface on the S-pole side of each pair of magnets.

[0023] [Aspect 13]

In the method for manufacturing a magnetic-disk glass substrate
 15 according to any one of aspects 10 to 12, the magnetism generating means and the stack are oscillated relative to the stacking direction during polishing.

[0024] [Aspect 14]

In the method for manufacturing a magnetic-disk glass substrate according to any one of aspects 10 to 13, the glass substrate has a disc shape
 20 having a circular through hole, the magnetism generating means includes an inner circumferential side means that is provided in the through holes of the glass substrates in the stack and forms magnetic field lines on the inner circumferential side that extend in a thickness direction of the glass substrates around the end surfaces on the inner circumferential side that are side wall
 25 surfaces of the through holes, and the end surface on the inner circumferential side of each glass substrate is brought into contact with the magnetic slurry held by the magnetic field lines on the inner circumferential side formed by the inner circumferential side means, and the end surface and the magnetic slurry are moved relative to each other in the contacting state to polish the end
 30 surfaces on the inner circumferential side.

[0025] [Aspect 15]

The method for manufacturing a magnetic-disk glass substrate is a method for manufacturing a magnetic-disk glass substrate including a step of performing end surface polishing on a glass substrate, wherein in the step of
 5 performing end surface polishing, a magnetic slurry containing polishing abrasive particles and a magnetic functional fluid is held by magnetic field lines formed by a magnetism generating means including a pair of magnets that are disposed in a separated state in a thickness direction of the glass substrate such that a surface on an N-pole side and a surface on an S-pole side
 10 are opposed to each other, and the end surface of the glass substrate is brought into contact with the magnetic slurry held by the magnetic field lines, and the end surface and the magnetic slurry are moved relative to each other in the contacting state to polish the end surface of the glass substrate.

[0026] [Aspect 16]

15 The method for manufacturing a magnetic-disk glass substrate is a method for manufacturing a magnetic-disk glass substrate including a step of performing end surface polishing on a glass substrate, wherein in the step of performing end surface polishing, magnetic field lines that extend in a thickness direction of the glass substrate are formed using a magnetism
 20 generating means, a magnetic slurry containing a magnetorheological fluid and polishing abrasive particles is held by the magnetic field lines to form a mass of the magnetic slurry, and an end surface of the glass substrate is brought into contact with the mass of the magnetic slurry, and the end surface and the mass are moved relative to each other in the contacting state to polish the glass
 25 substrate.

[0027] [Aspect 17]

In the method for manufacturing a magnetic-disk glass substrate according to aspect 16, the magnetism generating means includes a pair of magnets that are disposed in a separated state in the thickness direction of the
 30 glass substrate such that a surface on an N-pole side and a surface on an S-pole

side are opposed to each other.

[0028] [Aspect 18]

In the method for manufacturing a magnetic-disk glass substrate according to aspect 16 or 17, a spacer made of a non-magnetic substance is
5 provided between the surface on the N-pole side and the surface on the S-pole side of the pair of magnets.

[0029] [Aspect 19]

In the method for manufacturing a magnetic-disk glass substrate according to any one of aspects 16 to 18, the glass substrate has a disc shape
10 that has a circular through hole, the magnetism generating means includes an inner circumferential side means that is provided in the through hole of the glass substrate and forms magnetic field lines on the inner circumferential side that extend in the thickness direction of the glass substrate around the end surface on the inner circumferential side that is a side wall surface of the
15 through hole and an outer circumferential side means that is provided on the outer circumferential side of the glass substrate and forms magnetic field lines on the outer circumferential side that extend in a thickness direction of the glass substrate around the end surface on the outer circumferential side of the glass substrate, and the end surface on the inner circumferential side and the
20 end surface on the outer circumferential side are respectively brought into contact with the masses of the magnetic slurry formed by the inner circumferential side means and the outer circumferential side means, and the end surfaces and the masses are moved relative to each other in the contacting state to polish both the end surface on the inner circumferential side and the
25 end surface on the outer circumferential side.

[0030] [Aspect 20]

The method for manufacturing a magnetic-disk glass substrate is a method for manufacturing a plurality of magnetic-disk glass substrate including a step of stacking a plurality of glass substrates to form a stack of
30 glass substrates, and performing end surface polishing on each of the glass

substrates in the stack, wherein in the step of performing end surface polishing, magnetic field lines that extend in a stacking direction of the stack are formed at a plurality of positions using a magnetism generating means, a magnetic slurry containing a magnetorheological fluid and polishing abrasive particles is
5 held along the magnetic field lines at the plurality of positions to form a mass of the magnetic slurry around the end surface of the glass substrate at each of the plurality of positions, an end surface of each glass substrate in the stack is brought into contact with the mass of magnetic slurry, and the end surface and the mass are moved relative to each other in the contacting state to polish each
10 glass substrate in the stack.

[0031] [Aspect 21]

In the method for manufacturing a magnetic-disk glass substrate according to aspect 20, the magnetism generating means includes a plurality of pairs of magnets that are disposed in a separated state in a stacking direction
15 of the stack such that a surface on an N-pole side and a surface on an S-pole side are opposed to each other, and the plurality of magnets are provided at a plurality of positions in the stacking direction of the stack.

[0032] [Aspect 22]

In the method for manufacturing a magnetic-disk glass substrate according to aspect 20 or 21, a spacer made of a non-magnetic substance is
20 provided between the surface on the N-pole side and the surface on the S-pole side of each pair of magnets.

[0033] [Aspect 23]

In the method for manufacturing a magnetic-disk glass substrate according to any one of aspects 20 to 22, the magnetism generating means and
25 the stack are oscillated relative to the stacking direction during polishing.

[0034] [Aspect 24]

In the method for manufacturing a magnetic-disk glass substrate according to any one of aspects 20 to 23, the glass substrate has a disc shape
30 that has a circular through hole, the magnetism generating means includes an

inner circumferential side means that is provided in the through holes of the glass substrates of the stack and forms magnetic field lines on the inner circumferential side that extend in the thickness direction of the glass substrates around the end surfaces on the inner circumferential side that are
5 side wall surfaces of the through holes of the glass substrates and an outer circumferential side means that is provided on the outer circumferential side of the glass substrates of the stack and forms magnetic field lines on the outer circumferential side that extend in a thickness direction of the glass substrates around the end surfaces on the outer circumferential side of the glass
10 substrates, and the end surfaces on the inner circumferential side and the end surfaces on the outer circumferential side are respectively brought into contact with the masses of the magnetic slurry formed by the inner circumferential side means and the outer circumferential side means, and the end surfaces and the masses are moved relative to each other in the contacting state to polish both
15 the end surfaces on the inner circumferential side and the end surfaces on the outer circumferential side.

[0035] [Aspect 25]

The method for manufacturing a magnetic-disk glass substrate is a method for manufacturing a magnetic-disk glass substrate including a step of
20 performing end surface polishing on a glass substrate, wherein in the step of performing end surface polishing, a magnetic slurry containing a magnetorheological fluid and polishing abrasive particles is held along magnetic field lines formed by a magnetism generating means including a pair of magnets that are disposed in a separated state in a thickness direction of the
25 glass substrate such that a surface on an N-pole side and a surface on an S-pole side are opposed to each other to form a mass of the magnetic slurry around the end surface of the glass substrate, and the end surface of the glass substrate is brought into contact with the mass of the magnetic slurry, and the end surface and the mass are moved relative to each other in the contacting state to polish
30 the glass substrate.

[0036] [Aspect 26]

In the method for manufacturing a magnetic-disk glass substrate according to any one of aspects 1 to 25, the magnetic slurry has a viscosity of 1000 to 2000 [mPa·second] at a temperature of 20°C.

5 [0037] [Aspect 27]

In the method for manufacturing a magnetic-disk glass substrate according to any one of aspects 1 to 26, the magnetism generating means has a magnetic flux density of 0.3 to 0.8 [tesla].

[0038] [Aspect 28]

10 In the method for manufacturing a magnetic-disk glass substrate according to any one of aspects 1 to 27, a yield stress of the magnetic slurry is 30 to 60 kPa in a state in which a magnetic field of 0.4 [tesla] is applied.

[Advantageous Effects of the Invention]

[0039] With the above-described method for manufacturing a magnetic-disk
15 glass substrate, the processing rate of polishing can be increase above conventional rates and polishing can be performed efficiently, when polishing the end surface of a glass substrate.

[Brief Description of Drawings]

[0040] FIG. 1A is a schematic configuration diagram showing an example of a
20 magnetic disk produced using a magnetic-disk glass substrate, and FIG. 1B is a cross-sectional view of the example of a magnetic disk.

FIG. 2 is a diagram showing a flow of an embodiment of a method for manufacturing a magnetic-disk glass substrate.

FIGS. 3A to 3C are diagrams illustrating a polishing method according
25 to the present embodiment.

FIG. 4 is a diagram illustrating a state during polishing according to the present embodiment.

FIGS. 5A and 5B are diagrams illustrating a polishing method using a stack of magnetic-disk glass substrates according to the present embodiment.

30 FIG. 6 is a diagram illustrating a modified example of the polishing

method according to the present embodiment shown in FIG. 5.

FIG. 7 is a diagram illustrating another modified example of the present embodiment.

[Description of Embodiments]

5 [0041] Hereinafter, a method for manufacturing a magnetic-glass substrate of this embodiment will be described in detail.

It should be noted that a magnetorheological fluid (MRF) stated in the specification below is one of magnetic functional fluids. The magnetic functional fluids include a magnetic fluid (MF) and a magnetic compound fluid
10 (MCF) in addition to the magnetorheological fluid. A magnetic slurry stated in this specification includes at least polishing abrasive particles and a magnetorheological fluid.

[0042] (Magnetic disk and magnetic-disk glass substrate)

First, a magnetic disk produced using a magnetic-disk glass substrate
15 will be described with reference to FIGS. 1. FIG. 1A is a schematic configuration diagram showing an example of the magnetic disk produced using a magnetic-disk glass substrate. FIG. 1B is a schematic cross-sectional view of the magnetic disk.

[0043] As shown in FIG. 1A, a magnetic disk 1 has a ring shape in which a
20 circular hole is concentrically formed in the central portion of a disc shape, and rotates around an axis passing through the center of the ring as a rotation axis. This magnetic disk 1 has a predetermined diameter of, for example, a 2.5-inch magnetic disk or a 3.5-inch magnetic disk. As shown in FIG. 1B, the magnetic disk 1 includes a glass substrate 2 and at least magnetic layers 3A and 3B. It
25 should be noted that an adherent layer, a soft magnetic layer, a non-magnetic base layer, a perpendicular magnetic recording layer, a protecting layer and a lubricant layer, which are not shown in the diagram, are formed in addition to the magnetic layers 3A and 3B, for example. A Cr alloy is used in the adherent layer, for example. The adherent layer serves as a bonding layer
30 with the glass substrate 2. A CoTaZr alloy is used in the soft magnetic layer,

for example. A granular non-magnetic layer is used as the non-magnetic base layer, for example. A granular magnetic layer, for example, is used as the perpendicular magnetic recording layer. A material made of hydrogenated carbon is used in the protecting layer. A fluorine-based resin, for example, is used in the lubricant layer.

[0044] The magnetic disk 1 will be described by use of a more specific example. In this embodiment, an adherent layer made of CrTi, a soft magnetic layer made of CoTaZr/Ru/CoTaZr, a non-magnetic granular base layer made of CoCrSiO₂, a granular magnetic layer made of CoCrPt-SiO₂-TiO₂, and a protecting film made of a hydrogenated carbon are sequentially formed on each of the two main surfaces of the glass substrate 2 using an in-line type sputtering device. In addition, a lubricant layer made of perfluoropolyether is formed on the formed uppermost layer by a dipping method.

[0045] Aluminosilicate glass, soda-lime glass, borosilicate glass, or the like can be used as a material for a magnetic-disk glass substrate of this embodiment. In particular, aluminosilicate glass can be preferably used because it can be chemically strengthened and be used to produce a magnetic-disk glass substrate having excellent flatness of its main surfaces and excellent strength of the substrate.

[0046] Although there is no limitation on the composition of the magnetic-disk glass substrate of this embodiment, it is preferable to use aluminosilicate glass that contains, in terms of oxide amount in mol%, SiO₂ in an amount of 50 to 75%, Al₂O₃ in an amount of 1 to 15%, at least one component selected from Li₂O, Na₂O and K₂O in a total amount of 12 to 35%, at least one component selected from MgO, CaO, SrO, BaO and ZnO in a total amount of 0 to 20%, and at least one component selected from ZrO₂, TiO₂, La₂O₃, Y₂O₃, Ta₂O₅, Nb₂O₅ and HfO₂ in a total amount of 0 to 10% as the aluminosilicate glass.

[0047] Next, a flow of a method for manufacturing a magnetic-disk glass substrate will be described with reference to FIG. 2. FIG. 2 is a diagram showing a flow of the embodiment of a method for manufacturing a

magnetic-disk glass substrate.

As shown in FIG. 2, first, a plate glass blank having a pair of main surfaces is molded (step S10). Next, an annular glass substrate is produced by scribing the molded glass blank (step S20). Thus, a magnetic-disk glass substrate (referred to as merely "glass substrate" hereinafter) having a circular through hole that has a central point at the center of the glass substrate is obtained. Next, shaping processing (chamfering processing) is performed on the scribed glass substrate (step S30). Next, grinding is performed on the glass substrate (step S40). Next, end surface polishing is performed on the glass substrate (step S50). Next, first polishing is performed on the main surfaces of the glass substrate (step S60). Next, second polishing is performed on the glass substrate (step S70). A magnetic-disk glass substrate that satisfies the requirement for surface unevenness is obtained through the above steps. It should be noted that a circular glass substrate is produced from a glass blank by the steps from the glass blank molding step (step S10) to the shaping processing step (step S30). These steps are not always necessary, and may be omitted as appropriate. Also, the order of the steps can be changed as appropriate. Hereinafter, the steps will be described in detail.

[0048] (a) Glass blank molding step (step S10)

In glass blank molding, a float method is used, for example. In the glass blank molding step, first, a sheet of plate glass having, for example, the above-described composition is obtained by continuously pouring molten glass in a bath filled with molten metal such as tin. The molten glass flows in the traveling direction in the bath in which temperature is strictly controlled, and as a result, a sheet of plate glass that is adjusted to have a desired thickness and width is formed. A plate glass blank having a predetermined shape (for example, a quadrangular shape in a plan view) from which a magnetic-disk glass substrate is to be made is cut out from this sheet of plate glass. Since the molten tin in the bath has a flat surface, the plate glass blank obtained by a float method has a surface having a sufficiently high flatness.

Also, for example, a press molding method other than a float method can be used to mold a plate glass blank. In molding of a plate glass blank by press molding, a glass gob (glass mass) constituted by molten glass is supplied on a lower mold serving as a gob-forming receiving mold, and the glass gob is
5 press-molded using the lower mold and an upper mold serving as an gob-forming opposing mold. Thus, a disc-shaped glass blank from which a magnetic-disk glass substrate is to be made is produced.

It should be noted that a method for manufacturing a plate glass blank is not limited to the above-described methods and a plate glass blank can also
10 be manufactured using a known manufacturing method such as a down draw method, a redraw method or a fusion method. A disc-shaped glass blank from which a magnetic-disk glass substrate is to be made is cut out from a sheet of plate glass made by a known manufacturing method such as a float method, a down draw method, a redraw method or a fusion method through a scribing
15 step, which will be described below.

[0049] (b) Scribing step (step S20)

Next, the scribing step will be described. After the glass blank molding step, the molded glass blank is scribed in the scribing step.

Here, the term "scribe" means formation of two cutting lines (linear
20 marks) having a concentric shape (concentric circle on the inner circumferential side and concentric circle on the outer circumferential side) on the surface of the glass blank in order to make a ring-shaped glass substrate having a predetermined size from the molded glass blank. The glass blank on which two concentric circles are scribed is partially heated, and the outer portion of
25 the concentric circle on the outer circumferential side and the inner portion of the concentric circle on the inner circumferential side are removed due to the difference in thermal expansion of the glass blank. Thus, a ring-shaped glass substrate in which a circular through hole is formed is obtained. It should be noted that a disc-shaped glass substrate in which a circular through hole is
30 formed can also be obtained by using a core drill to form a circular hole in the

glass blank.

[0050] (c) Shaping processing step (step S30)

Next, the shaping processing step will be described. The shaping processing step includes chamfering processing performed on the end portions of the glass substrate (chamfering processing performed on the end surface on the outer circumferential side and the end surface on the inner circumferential side) after the scribing step. The chamfering processing is shaping processing for chamfering the end surface on the outer circumferential side and the end surface on the inner circumferential side of the glass substrate after the scribing step. The chamfered inclination angle with respect to the main surface is, for example, 40 to 50 degrees, and preferably substantially 45 degrees. A glass substrate having a predetermined cross-sectional shape is produced through this shaping processing.

[0051] (d) Grinding step (step S40)

In the grinding step, grinding processing is performed on the main surfaces of the glass substrate using a double-side grinding device provided with a known planetary gear mechanism including an upper surface plate, a lower surface plate, an internal gear, a carrier, and a sun gear. Specifically, the main surfaces on the two sides of the glass substrate are ground while the end surface on the outer circumferential side of the glass substrate is held in a holding hole provided in a holding member of the double-side grinding device. The double-side grinding device has a pair of upper and lower surface plates (upper surface plate and lower surface plate) and the glass substrate is held between the upper surface plate and the lower surface plate. In order to hold the glass substrate therebetween, the glass substrate is held in a holding hole provided in the disc-shaped carrier, and the carrier is sandwiched between the upper surface plate and the lower surface plate in this state. 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, so that the two main surfaces of the glass substrate can be ground.

It should be noted that fixed abrasive particles provided on the surface plates or a polishing slurry including loose abrasive particles can be used in the grinding.

[0052] (e) End surface polishing step (step S50)

5 Next, the end surface polishing step will be described. In end surface polishing, a magnetic slurry including polishing abrasive particles and a magnetorheological fluid is held in magnetic field lines to form a mass of the magnetic slurry constituted by hardened magnetic slurry, and then this mass and both the end surface on the inner circumferential side and the end surface
10 on the outer circumferential side are respectively brought into contact and moved relative to each other to polish the end surface on the inner circumferential side and the end surface on the outer circumferential side of the glass substrate. For example, microparticles of cerium oxide, zirconium oxide, or the like are used as the polishing abrasive particles in the magnetic slurry.
15 Moreover, the machining allowance by the end surface polishing is 10 μm or less, and more preferably 5 μm or less. By polishing the end surfaces, contamination by attached waste and the like, and damage or impairment such as scratches on the end surfaces of the glass substrate are eliminated, and therefore, it is possible to prevent thermal asperity. Furthermore, it is
20 possible to prevent the deposition of ions such as sodium and potassium that causes corrosion. The end surface polishing of this embodiment is capable of performing polishing in a shorter time compared with a conventional end surface polishing method, such as a method for polishing the end surfaces of a glass substrate using a brush with a polishing slurry, and a conventional
25 magnetic polishing method, and has extremely good production efficiency. The end surface polishing will be described later.

[0053] (f) First polishing step (step S60)

 Next, first polishing is performed on the main surfaces of the ground glass substrate. Specifically, the main surfaces on the two sides of the glass
30 substrate are polished while the end surface on the outer circumferential side

of the glass substrate is held in a holding hole provided in a holding member of a double-side polishing device.

[0054] In the first polishing step, the glass substrate is polished using a known double-side polishing device configured in the same manner as the double-side grinding device to be used for grinding (step S40) while supplying a polishing slurry. In the first polishing step, a polishing slurry including loose abrasive particles is used. For example, cerium oxide abrasive particles or zirconia abrasive particles are used as the loose abrasive particles for the first polishing. Also in the double side polishing device, as in the double-side grinding device, the glass substrate is held between a pair of upper and lower surface plates. Planar polishing pad (resin polisher, for example) having an annular shape as a whole are attached to the upper surface of the lower surface plate and the surface of the upper surface plate that is opposed to the glass substrate. 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, so that the two main surfaces of the glass substrate can be polished

[0055] (g) Second polishing (final polishing) step (step S70)

Next, second polishing is performed on the glass substrate. Also in second polishing, a double-side polishing device configured in the same manner as the double-side polishing device to be used in the first polishing is used. The type and size of loose abrasive particles and the hardness of a resin polisher are adjusted as appropriate, and the second polishing is performed.

[0056] For example, microparticles of colloidal silica or the like suspended in a slurry are used as the loose abrasive particles for the second polishing. The polished glass substrate is cleaned to provide a magnetic-disk glass substrate.

Although the second polishing step is not necessarily essential, it is preferable to perform the second polishing step because it is possible to make the level of surface unevenness of the main surfaces of the glass substrate more favorable. By performing the second polishing step, it is possible to cause the main surfaces to have a roughness (Ra) of 0.1 nm or less and a microwaviness

(MW-Rq) of 0.1 nm or less.

[0057] In this manner, the glass substrate that has been subjected to the second polishing serves as a magnetic-disk glass substrate that satisfies the requirement for surface unevenness. It should be noted that chemical strengthening processing by ion exchange may be performed as needed before and after the above-described polishing steps and between the first polishing and the second polishing. For example, chemical strengthening may be performed on the glass substrate before the (e) end surface polishing step (step S50) and then the (e) end surface polishing step (step S50) may be performed on the end surfaces of the chemically strengthened glass substrate. This is preferable because it is possible to remove foreign matter attached to the surfaces of the glass substrate during the chemical strengthening processing. A known method may be used to perform the chemical strengthening processing.

[0058] (End surface polishing)

The end surface polishing performed in step S50 will be described more specifically. FIGS. 3A to 3C and FIG. 4 are diagrams illustrating a polishing method of the end surface polishing according to the present embodiment in an easy-to-understand manner.

An end surface polishing device 10 polishes the end surface of a glass substrate using a magnetism generating means and a magnetic slurry. In the device 10, first, magnetic field lines that extend in the thickness direction of a glass substrate 11 are formed using a magnet 12 and a magnet 14 that serve as a magnetism generating means, a mass 20 of the magnetic slurry is made by providing the magnetic slurry in these magnetic field lines 11, and the mass 20 of the magnetic slurry is held by these magnetic field lines along the magnetic field lines. By moving the glass substrate 11 and the mass 20 relative to each other in a state in which the end surface of the glass substrate 11 comes into contact with the mass 20 of the magnetic slurry held by the magnetic field lines, the end surface of the glass substrate 11 is polished.

FIGS. 3A to 3C and FIG. 4 illustrate polishing performed on the end surface on the inner circumferential side of the glass substrate. An outline of the end surface polishing device 10 will be described. As shown in FIG. 3A, the device 10 includes a pair of magnets 12 and 14, which are permanent magnets, a spacer 16, and an exterior member 18 that has a hollow columnar shape and is made of a non-magnetic substance such as stainless steel. The magnets 12 and 14 and the spacer 16 are incorporated into the exterior member 18. The glass substrate 11 on which end surface polishing is to be performed is held by a holder (not shown). The exterior member 18 is inserted through a circular through hole 11a of the glass substrate 11 held by the holder, and the mass 20 (see FIG. 3C and FIG. 4) of the magnetic slurry, which will be described later, and the end surface on the inner circumferential side of the glass substrate 11 are brought into contact with each other. The exterior member 18 of the device 10 and a holder (not shown) for holding the glass substrate 11 are mechanically connected to a driving motor (not shown). By rotating the exterior member 18 and the holder to move the end surface of the glass substrate 11 and the mass 20 relative to each other, it is possible to polish the end surface on the inner circumferential side of the glass substrate 11. For example, the exterior member 18 and the holder for holding the glass substrate 11 are rotated in opposite directions preferably at a relative circumferential speed between the exterior member 18 and the holder of 50 to 300 m/minute, and more preferably 40 to 100 m/minute. That is, the magnetic slurry is formed in an annular shape on the surface of the exterior member 18 (rotation body), which has a central axis and is rotatable about the central axis. When the end surface on the inner circumferential side of the glass substrate 11 is polished, the magnetic slurry is rotated by the rotation of the exterior member 18. It is preferable that the entire circumference of the end surface on the inner circumferential side of the glass substrate 11 and the entire circumference of the magnetic slurry are brought into contact and the glass substrate 11 is rotated in the opposite direction to the direction in which the

glass substrate 11 is rotated. Since the magnetic slurry is formed in an annular shape, it is possible to polish the end surface on the inner circumferential side, which is an inner wall surface of the circular through hole of the glass substrate 11, such that the shape of the circular hole is not deformed. In this case, the rotation rate of the glass substrate 11 is set to, for example, 500 to 4000 rpm and the rotation rate of the magnetic slurry is set to, for example, 50 to 300 rpm. It should be noted that, as described later, in the case where the end surface on the outer circumferential side of the glass substrate 11 is polished, it is preferable that the rotation rate of the glass substrate 11 is set to, for example, 500 to 4000 rpm and the rotation rate of the magnetic slurry is set to, for example, 50 to 300 rpm.

It should be noted that one of the end surface of the glass substrate 11 and the mass 20 may be fixed and the other may be rotated as long as the end surface of the glass substrate 11 and the mass 20 can be moved relative to each other. However, in the case where the magnetic slurry and the glass substrate 11 are rotated in the same direction, the polishing processing rate is likely to vary and the temperature of the magnetic slurry becomes excessively high, thus reducing the life of the magnetic slurry. In this regard, it is preferable to rotate the glass substrate 11 and the magnetic slurry in opposite directions.

[0059] The end surface polishing will be described more specifically. The magnet 12 and the magnet 14 are close to each other, serve as a magnetism generating means, and thus form magnetic field lines 19 as shown in FIG. 3B. The magnetic field lines 19 extend so as to project outward from the center between the magnets 12 and 14, and extend in the thickness direction of the glass substrate 11. In the example shown in FIG. 3B, a pair of magnets that are disposed in a separated state in the thickness direction of the glass substrate such that the surface on the N-pole side and the surface on the S-pole side are opposed to each other is used as the magnetism generating means. "The surfaces are opposed to each other" means that two surfaces face each other in parallel, that is, are directly opposite each other. The spacer 16 made

of a non-magnetic substance is provided between the magnets 12 and 14 such that the distance between the end surface on the N-pole side of the magnet 12 and the end surface on the S-pole side of the magnet 14 is set to a distance determined in advance. The distance between the end surface on the N-pole side of the magnet 12 and the end surface on the S-pole side of the magnet 14 is set to a distance determined in advance, in order to form the mass 20 of the magnetic slurry as shown in FIG. 3C around the outer circumference of the exterior member 18 by causing the magnetic fields lines 19 to project outward as shown in FIG. 3B. Since the mass 20 is a portion that comes into contact with the end surface of the glass substrate 11 and that is moved relative to the end surface, the magnetic force is desirably strong to some extent from the viewpoint of ensuring the rigidity of the mass 20. Therefore, it is preferable that the distance between the end surface on the N-pole side of the magnet 12 and the end surface on the S-pole side of the magnet 14 is short. However, in the case where the distance is excessively short, the magnetic field lines are unlikely to project outward, thus making it impossible to sufficiently form the mass 20. Therefore, the distance between the end surface on the N-pole side of the magnet 12 and the end surface on the S-pole side of the magnet 14 is determined to be within a predetermined certain range.

[0060] It is preferable that the end surface polishing of this embodiment is performed on the glass substrate such that the end surface of the glass substrate 11 is pressed against the inside of the mass 20 in the direction orthogonal to the magnetic field lines because the polishing processing rate is increased. The mass 20 has a significant effect on the end surface of the glass substrate 11 by pressing against the end surface in the direction orthogonal to the magnetic field lines, and thus promoting polishing.

Moreover, the end surface of the glass substrate 11 generally includes a side wall surface that extends in the direction orthogonal to both of the glass main surfaces of the glass substrate 11, and chamfered surfaces that connect this side wall surface and both of the glass main surfaces and that are inclined

with respect to the glass main surfaces. It is preferable to simultaneously polish the side wall surface and the chamfered surfaces when the end surface of the glass substrate 11 is polished. With the glass substrate of this embodiment, it is possible to perform the end surface polishing on the side wall surface and the chamfered surfaces simultaneously at a high polishing rate, thus making it possible to efficiently perform end surface polishing.

It is preferable that the end surface of the glass substrate 11 of this embodiment is pressed against the inside of the mass 20 of the magnetic slurry so as to come into contact with a portion inside the mass 20 held by the magnetic field lines that connect the N-pole of the magnet 12 and the S-pole of the magnet 14, that is, by closed magnetic field lines in which magnetic field lines extend from the N-pole or the S-pole and end at the S-pole or the N-pole. The portion of the magnetic slurry held along the magnetic field lines that connect the N-pole of the magnet 12 and the S-pole of the magnet 14 has a higher rigidity compared with a portion held by magnetic field lines that do not end at the pole of the magnet, thus achieving a high polishing processing rate.

It should be noted that although the glass substrate 11 is pressed into the inside of the mass 20 such that the side wall surface and the chamfered surfaces are simultaneously polished as described above, a portion of the main surface of the glass substrate that comes into contact with the mass 20 is not substantially polished. In the vicinity of the main surface of the glass substrate, the magnetic field lines that are closed between the N-pole and the S-pole are broken due to the glass substrate interrupting the magnetic field lines, and thus the hardness of the mass of the magnetic slurry tends to decrease. Therefore, the processing rate of polishing performed on the main surface of the glass substrate becomes extremely low, and thus the main surface is not substantially polished during polishing performed on the end surface of the glass substrate.

Moreover, in this embodiment, it is preferable that the magnetic-disk glass substrate to be polished has a thin plate shape, and it is more preferable

that the magnetic-disk glass substrate has a thickness of 1 mm or less. In the present invention, it is preferable to polish the end surface of the glass substrate having a thin plate shape.

It should be noted that although permanent magnets are used as a magnetism generating means in the example shown in FIGS. 3A to 3C and FIG. 4, electromagnets can also be used as described later. Moreover, although the spacer 16 is used in order to ensure a constant distance between the end surface on the N-pole side of the magnet 12 and the end surface on the S-pole side of the magnet 14, the magnets 12 and 14 can be fixed to the exterior member 18 to ensure the constant distance between the end surface on the N-pole side of the magnet 12 and the end surface on the S-pole side of the magnet 14 without the spacer 16.

[0061] A fluid containing, for example, non-polar oil that contains magnetic microparticles constituted by Fe having a size of 0.1 to 10 μm in an amount of 3 to 5 g/cm^3 and a surfactant is used as the magnetorheological fluid of the magnetic slurry used in the end surface polishing. Non-polar oil or polar oil has, for example, a viscosity of 100 to 1000 (mPa·second) at room temperature (20°C).

The mass 20, which is made from the magnetic slurry, contains the polishing abrasive particles as well as magnetic particles when the mass is made from the magnetorheological fluid containing magnetic microparticles on the magnetic field lines. The polishing abrasive particles in the magnetorheological fluid are pushed out to a portion in which magnetic force gradient is low by a magnetic levitation effect, and are thus present more toward the vicinity of the end surface of the glass substrate that is to be polished. In addition, the mass having relatively high elastic properties is formed by the magnetic field lines, and therefore, it is possible to efficiently perform polishing by pressing the end surface of the glass substrate against the mass 20. That is, the processing rate can be increased above conventional rates, and polishing can thus be performed efficiently.

[0062] Known glass substrate polishing abrasive particles such as cerium oxide, colloidal silica, zirconia oxide, alumina abrasive particles, or diamond abrasive particles can be used as the polishing abrasive particles contained in the magnetic slurry. The polishing abrasive particles have a particle diameter of, for example, 0.5 to 3 μm . Using the polishing abrasive particles having a particle diameter within this range makes it possible to favorably polish the end surface on the inner circumferential side of the glass substrate. The polishing abrasive particles are contained in the magnetic slurry in an amount of, for example, 3 to 15 vol%.

[0063] It is preferable that the concentration of the magnetorheological fluid is adjusted such that the magnetic slurry has a viscosity of 1000 to 2000 [mPa·second] at room temperature (20°C) because this allows the mass 20 of the magnetic slurry to be formed and end surface polishing to be efficiently performed. If the viscosity is low (the concentration of the magnetorheological fluid is low), the mass 20 is not readily formed, and it is difficult to perform polishing by moving the mass 20 relative to the end surface of the glass substrate 11 in a state in which the mass 20 is pressed against the end surface. On the other hand, in the case where the magnetic slurry has an excessively high viscosity, the mass 20 is formed in line with the shape of the end portion of the glass substrate 11 during polishing, and it is difficult to form a uniformly pressed state. Moreover, it is preferable that the magnetic flux density in the magnetism generating means is 0.3 to 0.8 [tesla] because this allows the mass 20 of the magnetic slurry to be formed and end surface polishing to be efficiently performed. Furthermore, the yield stress of the magnetorheological fluid is preferably 30 kPa or more in a state in which the magnetic field of 0.4 [tesla] is applied, and more preferably 30 to 60 kPa.

[0064] The yield stress (yield shearing stress) of the magnetorheological fluid can be determined by, for example, the following method.

The relationship between the shearing speed and the shearing stress of the magnetorheological fluid is determined using a device obtained by

incorporating a magnetic field applying means (e.g., permanent magnets or electromagnets) that can apply a magnetic field of 0.4 [tesla] in a rotational viscometer, and the determined relationship between the shearing speed and the shearing stress is approximated using the known Casson's equation, thus making it possible to determine the yield stress of the magnetorheological fluid.

The above-described yield stress affects the pressure that is applied to the glass substrate from the magnetic slurry, that is, shearing stress when the magnetic slurry held by the magnetic field and the end surface on the outer circumferential side of the glass substrate are moved relative to each other. Accordingly, the higher the yield stress of the magnetic slurry is (the higher the shearing stress when the magnetic slurry flows is), the more efficiently polishing by the contact between the polishing abrasive particles and the glass substrate is performed, thus making it possible to increase the processing rate of end surface polishing.

[0065] In this manner, the magnetic slurry is formed in an annular shape on the surface of the exterior member 18, which is a rotation body that has a central axis and that is rotatable about the central axis. In this case, when the end surface on the inner circumferential side of the glass substrate 11 is polished, it is preferable that the magnetic slurry is rotated by the rotation of the rotation body and the entire circumference of the end surface on the inner circumferential side of the glass substrate 11 and the entire circumference of the magnetic slurry are brought into contact and the glass substrate 11 is rotated in the opposite direction to the direction in which the glass substrate 11 is rotated because the processing rate of polishing performed on the end surface on the inner circumferential side is increased.

It should be noted that the surface of the exterior member 18, which is a rotation body, may be the surface of a cylinder having a constant curvature radius or a groove that extends around the rotation body may be provided on the surface of the rotation body. It is possible to dispose the magnetic slurry in this groove.

[0066] (Modified Example 1)

Although FIGS. 3A to 3C and FIG. 4 illustrate polishing performed on the end surface on the inner circumferential side of the glass substrate 11, it is possible to polish the end surface on the outer circumferential side of the glass substrate by the same method. Modified Example 1 (not shown) is an example in which polishing of the end surface on the outer circumferential side of the glass substrate 11 is performed simultaneously with polishing of the end surface on the inner circumferential side.

In Modified Example 1, the exterior member 18 in which the magnets 12 and 14 and the spacer 16 shown in FIGS. 3A to 3C are incorporated is disposed near the end surface on the outer circumferential side of the glass substrate 11 and the magnetic slurry is held by the magnetic field lines formed on the outer circumferential side of the exterior member 18 by the magnets 12 and 14 along the magnetic field lines, thus forming the mass 20 of the magnetic slurry. By moving this mass 20 and the end surface on the outer circumferential side of the glass substrate relative to each other in a state in which the mass 20 and the end surface are in contact, the end surface on the outer circumferential side of the glass substrate 11 is polished.

[0067] That is, Modified Example 1 includes, as the magnetism generating means, an inner circumferential side means that provides the magnets 12 and 14 shown in FIGS. 3A to 3C in the through hole 11a of the substrate 11 and forms magnetic field lines, and an outer circumferential side means that provides the magnets 12 and 14 on the outer circumferential side of the substrate 11 in the same manner as the magnets 12 and 14 shown in FIGS. 3A to 3C and forms magnetic field lines. The inner circumferential side means forms magnetic field lines on the inner circumferential side that extend in the thickness direction of the glass substrate 11 around the end surface on the inner circumferential side of the glass substrate 11 that surrounds the through hole 11a. The outer circumferential side means forms magnetic field lines on the outer circumferential side that extend in the thickness direction of the glass

substrate 11 around the end surface on the outer circumferential side of the glass substrate 11. End surface polishing is performed such that the end surface on the inner circumferential side and the end surface on the outer circumferential side of the glass substrate 11 are respectively brought into contact with the mass 20 of the magnetic slurry formed by the inner circumferential side means and the mass 20 formed by the outer circumferential side means and the end surfaces and the masses are moved relative to each other in this state, and thus both the end surface on the inner circumferential side and the end surface on the outer circumferential side are polished. Accordingly, in Modified Example 1, polishing of the end surface on the outer circumferential side can be performed simultaneously with polishing of the end surface on the inner circumferential side of the glass substrate 11 shown in FIGS. 3A to 3C and FIG. 4, thus achieving efficient end surface polishing. That is, the processing rate can be increased above conventional rates, and polishing can thus be performed efficiently.

[0068] (Modified Example 2)

FIGS. 5A and 5B show Modified Example 2 of the end surface polishing.

Modified Example 2 is an example in which not the end surface on the inner circumferential side of one glass substrate but the end surfaces on the inner circumferential side of a plurality of glass substrates are simultaneously polished.

In Modified Example 2, a plurality of pairs of magnets are used to form magnetic field lines that extend in the stacking direction of a stack of the glass substrates at a plurality of positions. By disposing the magnetic slurry at the plurality of positions, the magnetic slurry is held by the magnetic field lines to make masses of the magnetic slurry at the plurality of positions. At each position, the end surface of the glass substrate in the stack of the glass substrates is brought into contact with the mass held by the magnetic field lines and the end surface and the mass are moved relative to each other in this state, and thus the end surface of the glass substrate is polished. Thus, it is

possible to perform end surface polishing on the plurality of glass substrates in a short time.

A device 30 shown in FIG. 5A includes the exterior member 18, magnets 12, 14, 32, 34, and 36, and spacers 16, 38, 40, and 42. The exterior member 18, the magnets 12 and 14, and the spacer 16 are configured in the same manner as the exterior member 18, the magnets 12 and 14, and the spacer 16 shown in FIG. 3A, respectively. Moreover, the magnets 32, 34, and 36 are configured in the same manner as the magnets 12 and 14, and the spacers 38, 40, and 42 are configured in the same manner as the spacer 16. Accordingly, descriptions of the exterior member 18, the magnets 12, 14, 32, 34, and 36, and the spacers 16, 38, 40, and 42 are omitted.

[0069] The magnets are incorporated into the exterior member 18 in a stacked state such that the end surface on the N-pole side of a magnet and the end surface on the S-pole side of the neighboring magnet oppose each other separated by a constant interval. Accordingly, masses 20, 52, 54, and 56 of the magnetic slurry are formed by such an exterior member 18 at a plurality of (four) positions in the longitudinal direction of the exterior member 18 along the magnetic field lines formed outside the exterior member 18. The exterior member 18 on which the masses 20, 52, 54, and 56 are formed is inserted through the circular through holes that are provided to have central points at the centers of the bundled glass substrates 11, 44, 46, and 48 (the end surface of each glass substrate is chamfered), and the masses 20, 52, 54, and 56 are brought into contact with the end surfaces on the inner circumferential side of the glass substrates 11, 44, 46, and 48. Accordingly, by moving the masses 20, 52, 54, and 56 and the end surfaces on the inner circumferential side of the glass substrates 11, 44, 46, and 48 relative to each other, it is possible to simultaneously polish the end surfaces on the inner circumferential side of the glass substrates 11, 44, 46, and 48. The glass substrates 11, 44, 46, and 48 are integrated into a stack using an adhesive or the like. Here, any adhesive can be used as the adhesive for forming the stack as long as the main surfaces of

the glass substrates 11, 44, 46, and 48 can be adhered to or detached from each other. For example, an ultraviolet curing resin adhesive is easily cured by irradiation of ultraviolet rays having a predetermined wavelength, and therefore, using the ultraviolet curing resin adhesive makes it easy to perform the adhering operation. Moreover, as the ultraviolet curing resin, a resin that enables, using warm water or organic solvent, easy detachment of the glass substrates 11, 44, 46, and 48 that have been adhered to each other is preferable. Wax, photocurable resin, visible light curing resin, or the like can also be used as the adhesive in addition to the ultraviolet curing resin. Since wax becomes soft and turns into a liquid state at a predetermined temperature and turns into a solid state at ambient temperature, using the wax makes it easy to perform the adhering and detaching operation on the glass substrates 11, 44, 46, and 48. Spacers may be sandwiched and adhered thereto instead of the adhesive. In the case where spacers are adhered between the glass substrates 11, 44, 46, and 48 instead of the adhesive, thin spacers made from a resin material, a fiber material, a rubber material, a metal material, a ceramic material, or the like can be used. The bundle of the glass substrates 11, 44, 46, and 48 is held by a holder (not shown).

[0070] That is, in a step of performing end surface polishing, the magnets 12, 14, 32, 34, and 36 are used as magnetism generating means to form magnetic field lines that extend in the stacking direction of the stack, which is a bundle of the glass substrates 11, 44, 46, and 48, at a plurality of positions, and the magnetic slurry is held along the magnetic field lines at the plurality of positions to form the masses 20, 52, 54, and 56 of the magnetic slurry around the end surfaces of the glass substrates at the plurality of positions. The end surfaces on the inner circumferential side of the glass substrates 11, 44, 46, and 48 are respectively brought into contact with the masses 20, 52, 54, and 56 of the magnetic slurry and the end surfaces and the masses are moved relative to each other in this state, and thus the glass substrates are polished. Accordingly, it is possible to simultaneously polish the end surfaces on the

inner circumferential side of a plurality of glass substrates, thus achieving efficient end surface polishing. That is, the processing rate can be increased above conventional rates, and polishing can thus be performed efficiently.

[0071] It should be noted that it is preferable that the positions at which the masses 20, 52, 54, and 56 are formed are adjusted by adjusting the spacers provided between the magnets such that the intervals between the glass substrates 11, 44, 46, and 48 are equal to the intervals between the masses 20, 52, 54, and 56, and the end surfaces on the inner circumferential side of the glass substrates 11, 44, 46, and 48 simultaneously come into contact with the respective masses 20, 52, 54, and 56. Considering the case where the end surfaces on the inner circumferential side of the glass substrates 11, 44, 46, and 48 do not simultaneously come into contact with the respective masses 20, 52, 54, and 56, it is preferable that the magnets 12, 14, 32, 34, and 36 serving as magnetism generating means and the bundle of the glass substrates 11, 44, 46, and 48, which is a stack, are oscillated relative to the stacking direction of the stack (the direction in which the exterior member 18 extends) during polishing. Due to the oscillation, the end surface on the inner circumferential side of the glass substrates 11, 44, 46, and 48 uniformly come into contact with the respective masses 20, 52, 54, and 56 during polishing, and thus can be uniformly polished. In the case where a stack obtained by bundling the glass substrates using, for example, an adhesive is used, oscillation is performed at a stroke of, for example, about 0.1 to 20 mm at a speed of, for example, 24 to 600 (mm/minute). Thus, it is possible to uniformly polish the side end surfaces. This oscillation is not only performed in the end surface polishing performed on the stack of the glass substrates of Modified Example 2 but can also be applied in the case where the end surface of one glass substrate is polished as shown in FIG. 4. In this case, it is preferable to set the range of oscillation to about half of the thickness of the glass substrate.

[0072] (Modified Example 3)

FIG. 6 shows Modified Example 3 of the end surface polishing. In

Modified Example 3, as in Modified Example 2, the end surface on the inner circumferential side of each glass substrate of a stack, which is a bundle of the glass substrates obtained by adhering a plurality of the glass substrates 11, 44, 46, and 48 to each other using an adhesive, is polished, and the end surface on the outer circumferential side of each glass substrate is polished. That is, the exterior member 18 on which the masses 20, 52, 54, and 56 are formed is inserted through the circular through holes that are provided to have central points at the centers of the glass substrates 11, 44, 46, and 48, which are bundled by adhering the main surfaces to each other using an adhesive, and the masses 20, 52, 54, and 56 are brought into contact with the end surfaces on the inner circumferential side of the glass substrates 11, 44, 46, and 48.

At the same time, masses 62, 64, 66, and 68 of the magnetic slurry are formed on the surface of an exterior member 60 that is configured in the same manner as the exterior member 18 and that is provided on the outer circumferential side of the glass substrates in the stack. The exterior member 60 is positioned such that the masses 62, 64, 66, and 68 come into contact with the glass substrates 11, 44, 46, and 48. The exterior member 60 is mechanically connected to a driving motor (not shown) in the same manner as the exterior member 18 and is rotatable. Accordingly, by rotating the exterior member 18 and the exterior member 60 in a different direction to the magnetic disk 11, 44, 46, and 48, it is possible to simultaneously polish the end surface on the inner circumferential side and the end surface on the outer circumferential side of the glass substrates 11, 44, 46, and 48, thus achieving efficient end surface polishing.

[0073] That is, in a step of performing end surface polishing, as magnetism generating means, an inner circumferential side means that forms magnetic field lines and is provided in circular through holes of the glass substrates 11, 44, 46, and 48, which constitute the stack, and an outer circumferential side means that forms magnetic field lines and is provided on the outer circumferential side of the glass substrates 11, 44, 46, and 48, which constitute

the stack. The inner circumferential side means forms magnetic field lines on the inner circumferential side that extend in the thickness direction of the glass substrates 11, 44, 46, and 48 around the end surfaces on the inner circumferential side of the glass substrates that surround the circular through
5 holes of the glass substrates 11, 44, 46, and 48. The outer circumferential side means forms magnetic field lines on the outer circumferential side that extend in the thickness direction of the glass substrates 11, 44, 46, and 48 around the end surfaces on the outer circumferential side of the glass substrates 11, 44, 46, and 48. The end surfaces on the inner circumferential side and the end
10 surfaces on the outer circumferential side of the glass substrates 11, 44, 46, and 48 are brought into contact with the respective masses 20, 52, 54, 56, 62, 64, 66, and 68 formed at a plurality of positions by the inner circumferential side means and the outer circumferential side means, and the end surfaces and the masses are moved relative to each other in this state, thus simultaneously
15 polishing the end surfaces on the inner circumferential side and the end surfaces on the outer circumferential side. Accordingly, it is possible to simultaneously polish the end surfaces on the inner circumferential side of a plurality of glass substrates, thus achieving efficient end surface polishing. That is, the processing rate can be increased above conventional rates, and
20 polishing can thus be performed efficiently.

[0074] (Modified Example 4)

FIG. 7 shows Modified Example 4 of the end surface polishing. In Modified Example 4, electromagnets are used instead of the magnets 12 and 14, which are permanent magnets, as shown in FIGS. 3A to 3C and FIG. 4. That
25 is, two electromagnets 70 and 72 and a spacer 74 for maintain the distance between the electromagnet 70 and the electromagnet 72 are incorporated into the exterior member 18, and the electromagnets are connected to current sources 76 and 78 such that the opposed end surfaces of the electromagnets 70 and 72 serve as the S-pole and the N-pole. Accordingly, current flows in the
30 electromagnets 70 and 72, and thus magnetic field lines 82 are formed between

the electromagnets 70 and 72. Therefore, in the same manner as shown in FIGS. 3A to 3C and FIG. 4, by holding the magnetic slurry along the magnetic field lines, a mass of the magnetic slurry is formed along the magnetic field lines. Accordingly, by bringing this mass and the glass substrate into contact and moving them relative to each other, it is possible to polish the glass substrate. That is, as in the embodiment and Modified Examples 1 to 3, the processing rate can be increased above conventional rates, and polishing can thus be performed efficiently.

A current control unit 80 controls on/off of current flowing from the current sources 76 and 78 to the electromagnets 70 and 72 and the amount of current. For example, in order to remove a mass of polishing slurry from the exterior member 18, the current flowing in the electromagnets 70 and 72 need only be turned off. Moreover, in the case where the polishing ability of the polishing slurry in the mass decreases, it is also possible to increase the pressure at which the mass presses against the end surface of the glass substrate by increasing the rigidity of the mass of the polishing slurry in order to maintain the polishing ability. In this manner, Modified Example 4, which uses the electromagnets 70 and 72, has an effect that is not exhibited by the embodiment and Modified Examples 1 to 3, which use permanent magnets.

[0075] It should be noted that although the embodiment and Modified Examples 1 to 4 all have a shape in which the magnetic field lines project outward from the exterior member and thus the mass of the magnetic slurry projects from the exterior member, it is not necessary for the mass to project. Any mass can be used as long as the mass of magnetic slurry is formed by holding the magnetic slurry along the magnetic field lines.

[0076] [Experimental Examples]

In order to confirm the effect of the present invention, end surface polishing was performed on produced glass substrates.

The produced glass substrate had an outer diameter of 65 mm and a thickness of 0.8 mm, and in the shaping processing step, chamfering of 0.25 mm

in the thickness direction of the glass substrate was performed at an inclination angle of 45 degrees to the main surface.

[0077] (Working example)

As shown in FIG. 5B, a stack obtained by stacking glass substrates for 2.5-inch type magnetic disk using an adhesive to integrate the glass substrates was inserted into a polishing device provided with a columnar exterior member in which a plurality of magnets were incorporated. The incorporated magnets had a diameter of 19 mm and a thickness of 15 mm. Moreover, spacers made of stainless steel were interposed between the magnets. This limited the attraction between the magnets. A magnetic slurry was supplied so as to follow the surface of the exterior member, and masses of the magnetic slurry that projected from the surface of the exterior member were formed at a plurality of positions. The polishing abrasive particles in the magnetic slurry were pushed out to a portion in which magnetic force gradient was low by a magnetic levitation effect, and thus were present more toward the vicinity of the surface of the masses. The rotation rates of the end surfaces of the glass substrates in the stack and the exterior member were set to 700 rpm (relative circumferential speed of 87 m/minute), and polishing was performed by rotating the end surfaces and the exterior member in opposite directions. The processing time was set to 3 minutes. Since the intervals between the glass substrates in the stack of the working example were different from the intervals between the positions at which the masses of the magnetic slurry were formed, oscillation was performed at a stroke speed of 200 mm/minute and at a stroke length of 20 mm.

A slurry obtained by dispersing cerium oxide having an average particle diameter of 2 μm in a magnetorheological fluid obtained by dispersing Fe microparticles having an average particle diameter of 2 μm in non-polar oil (silicone oil) in an amount of 3 [g/cm³] was used as the polishing slurry to be used to polish the end surfaces of the glass substrates. Cerium oxide was contained in the magnetic slurry such that the concentration was 5 vol%.

Permanent magnets having a magnetic flux density of 0.5 [tesla] were used in the working example.

[0078] (Conventional examples 1 and 2)

Moreover, the end surface on the inner circumferential side was polished using a brush as conventionally performed (conventional example 1). The polishing of the end surface on the inner circumferential side using a brush was performed by a method described in JP H11-28649A. Furthermore, magnetic polishing using a magnetic slurry shown in FIG. 4 of JP 2005-50501A was performed (conventional example 2). Permanent magnets having a magnetic flux density of 0.5 [tesla] were used in the conventional example 2.

[0079] The glass substrates were removed at predetermined intervals from the start of polishing, and the surface roughness of the polished end surface was measured. A laser microscope was used to measure the surface roughness. Specifically, the end portion including the end surface of the glass substrate of each of the conventional examples and the working example was magnified 150 times using the above-described laser microscope, and the surface roughness was measured in a region of 50 μm square thereof. The maximum height R_z (defined by JIS B0601: 2001), which is a distance between the highest point and the lowest point in the measurement region, was determined.

In the working example, the processing time was 3 minutes, and the maximum height R_z of the polished surface was 0.15 μm . In the conventional example 1, the processing time was 30 minutes, and the maximum height R_z of the polished surface was 0.20 μm . In the conventional example 2, the processing time was 60 minutes, and the maximum height R_z of the polished surface was 0.30 μm . In addition, in brushing such as performed on the conventional example 1, a machining allowance of 20 μm or more was required to polish the end surface into a desired surface state. In contrast, it was confirmed that in the working example, a machining allowance of 10 μm or less was sufficient to polish the end surface into a desired surface state. From these results, it was understood that the working example on which end surface

polishing had been performed for a short time had a surface roughness that was as smooth as or smoother than that of the conventional examples 1 and 2. In particular, it was found that in the working example, favorable polishing that was equal to or better than that in the conventional example 1 could be performed in about one tenth of the time. That is, it was found that with the manufacturing method according to the present invention, it is possible to increase the processing rate above conventional rates when the end surface of the glass substrate is polished, and to thus perform polishing efficiently.

[0080] While the method for manufacturing a magnetic-disk glass substrate according to the present invention has been described in detail, the present invention is not limited to the above-described embodiment and modified examples, and it will be appreciated that various improvements and modifications can be made without departing from the spirit of the present invention.

For example, the exterior member 18 or 60 of the embodiment may be omitted, and the magnetic slurry may be brought into contact with the magnets and the spacers. Moreover, for example, the diameters of the spacers 16, 38, 40, 42, and 74 of the embodiment may be matched with the diameters of the magnets 12, 14, 32, 34, and 36.

[List of Reference Numerals]

[0081]	1	Magnetic disk
	2, 11, 44, 46, 48	Glass substrate
	3A, 3B	Magnetic layer
	10, 30	Device
	12, 14, 32, 34, 36	Magnet
	16, 38, 40, 42, 74	Spacer
	18, 60	Exterior member
	20, 52, 54, 56, 62, 64, 66, 68	Mass
	30	Device
	70, 72	Electromagnet

76, 78 Current source

80 Current control unit

CLAIMS

1. A method for manufacturing a magnetic-disk glass substrate
5 comprising a step of performing end surface polishing on a glass substrate,
the step of performing end surface polishing including:
forming magnetic field lines that extend in a thickness direction of the
glass substrate, using a magnetism generating means;
disposing a magnetic slurry containing polishing abrasive particles and
10 a magnetic functional fluid in the magnetic field lines to hold the magnetic
slurry along the magnetic field lines; and
polishing an end surface of the glass substrate by moving the end
surface and the magnetic slurry relative to each other, the end surface of the
glass substrate being brought into contact with the magnetic slurry held by the
15 magnetic field lines.
2. The method for manufacturing a magnetic-disk glass substrate
according to claim 1,
wherein the magnetic slurry forms a mass along the magnetic field
20 lines, and
the end surface of the glass substrate is pressed against an ~~the~~ inside of
the mass in a direction orthogonal to the magnetic field lines, and the end
surface of the glass substrate is polished.
- 25 3. The method for manufacturing a magnetic-disk glass substrate
according to claim 1 or 2,
wherein the end surface of the glass substrate includes a side wall
surface that extends in the direction orthogonal to both main surfaces of the
glass substrate and chamfered surfaces that connect the side wall surface and
30 both main surfaces and that are inclined with respect to the main surfaces, and

when the end surface of the glass substrate is polished, the side wall surface and the chamfered surfaces are simultaneously polished.

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

wherein the magnetism generating means includes a pair of magnets that are disposed in a separated state in the thickness direction of the glass substrate such that a surface on an N-pole side and a surface on an S-pole side are opposed to each other.

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

wherein the magnetism generating means includes a pair of magnets that are disposed in a separated state in the thickness direction of the glass
15 substrate such that a surface on an N-pole side and a surface on an S-pole side are opposed to each other, and

the end surface of the glass substrate is pressed against an inside of the magnetic slurry so as to come into contact with a portion inside the magnetic slurry held by the magnetic field lines that connect the N-pole and the S-pole.

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

wherein a spacer made of a non-magnetic substance is provided between the surface on the N-pole side and the surface on the S-pole side of the
25 pair of magnets.

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

wherein the glass substrate has a disc shape that has a circular through
30 hole having a central point at the center of the glass substrate,

the magnetism generating means includes an inner circumferential side means that is provided in the through hole of the glass substrate and forms magnetic field lines on the inner circumferential side that extend in the thickness direction of the glass substrate around the end surface on the inner circumferential side that is a side wall surface of the through hole, and

the end surface on the inner circumferential side of the glass substrate is brought into contact with the magnetic slurry held by the magnetic field lines on the inner circumferential side formed by the inner circumferential side means, and the end surface and the magnetic slurry are moved relative to each other in the contacting state to polish the end surface on the inner circumferential side.

8. The method for manufacturing a magnetic-disk glass substrate according to claim 7,

wherein the magnetic slurry is formed in an annular shape on a surface of a rotation body that has a central axis and is rotatable about the central axis, and

when the end surface on the inner circumferential side of the glass substrate is polished, the magnetic slurry is rotated due to the rotation of the rotation body, and the entire circumference of the end surface on the inner circumferential side of the glass substrate and the entire circumference of the magnetic slurry are brought into contact and the glass substrate is rotated in an opposite direction to a direction in which the glass substrate is rotated.

9. The method for manufacturing a magnetic-disk glass substrate according to claim 7 or 8,

wherein the magnetism generating means includes an outer circumferential side means that is provided on the outer circumferential side of the glass substrate and forms magnetic field lines on the outer circumferential side that extend in a thickness direction of the glass substrate around the end

surface on the outer circumferential side of the glass substrate, and

the end surface on the outer circumferential side of the glass substrate is brought into contact with the magnetic slurry held by the magnetic field lines on the outer circumferential side formed by the outer circumferential side means, and the end surface and the magnetic slurry are moved relative to each other in the contacting state to polish both the end surface on the inner circumferential side and the end surface on the outer circumferential side.

10. A method for manufacturing a plurality of magnetic-disk glass substrate comprising: a step of stacking a plurality of glass substrates to form a stack of glass substrates, and performing end surface polishing on each of the glass substrates in the stack,

the step of performing end surface polishing including:

forming magnetic field lines that extend in a stacking direction of the stack at a plurality of positions using a magnetism generating means;

disposing a magnetic slurry containing polishing abrasive particles and a magnetic functional fluid at the plurality of positions to hold the magnetic slurry along the magnetic field lines; and

polishing, at each of the plurality of positions, an end surface of the glass substrate in the stack by moving the end surface in the stack and the magnetic slurry relative to each other, the end surface of the glass substrate being brought into contact with the magnetic slurry held by the magnetic field lines.

11. The method for manufacturing a magnetic-disk glass substrate according to claim 10,

wherein the magnetism generating means includes a plurality of pairs of magnets, each pair disposed in a separated state in a stacking direction of the stack such that a surface on an N-pole side and a surface on an S-pole side are opposed to each other, and the plurality of magnets are provided at a

plurality of positions in the stacking direction of the stack.

12. The method for manufacturing a magnetic-disk glass substrate according to claim 10 or 11,

5 wherein a spacer made of a non-magnetic substance is provided between the surface on the N-pole side and the surface on the S-pole side of each pair of magnets.

13. The method for manufacturing a magnetic-disk glass substrate according to any one of claims 10 to 12,

wherein the magnetism generating means and the stack are oscillated relative to the stacking direction during polishing.

14. The method for manufacturing a magnetic-disk glass substrate according to any one of claims 10 to 13,

wherein the glass substrate has a disc shape having a circular through hole,

the magnetism generating means includes an inner circumferential side means that is provided in the through holes of the glass substrates in the stack and forms magnetic field lines on the inner circumferential side that extend in a thickness direction of the glass substrates around the end surfaces on the inner circumferential side that are side wall surfaces of the through holes, and

the end surface on the inner circumferential side of each glass substrate is brought into contact with the magnetic slurry held by the magnetic field lines on the inner circumferential side formed by the inner circumferential side means, and the end surface and the magnetic slurry are moved relative to each other in the contacting state to polish the end surfaces on the inner circumferential side.

15. A method for manufacturing a magnetic-disk glass substrate

comprising: a step of performing end surface polishing on a glass substrate,

the step of performing end surface polishing including:

holding a magnetic slurry containing polishing abrasive particles and a magnetic functional fluid by magnetic field lines formed by a magnetism
5 generating means including a pair of magnets that are disposed in a separated state in a thickness direction of the glass substrate such that a surface on an N-pole side and a surface on an S-pole side are opposed to each other; and

polishing an end surface of the glass substrate by moving the end
surface and the magnetic slurry relative to each other, the end surface of the
10 glass substrate being brought into contact with the magnetic slurry held by the magnetic field lines.

16. The method for manufacturing a magnetic-disk glass substrate according to any one of claims 1 to 15,

15 wherein the magnetic slurry has a viscosity of 1000 to 2000 [mPa second] at a temperature of 20°C.

17 The method for manufacturing a magnetic-disk glass substrate according to any one of claims 1 to 16,

20 wherein the magnetism generating means has a magnetic flux density of 0.3 to 0.8 [tesla].

18. The method for manufacturing a magnetic-disk glass substrate according to any one of claims 1 to 17,

25 wherein a yield stress of the magnetic slurry is 30 to 60 kPa in a state in which a magnetic field of 0.4 [tesla] is applied.