

DESCRIPTION

POLISHING BRUSH, POLISHING METHOD, POLISHING APPARATUS, AND METHOD OF MANUFACTURING GLASS SUBSTRATE FOR MAGNETIC DISK

Technical Field

[0001]

The present invention relates to polishing brushes or abrasive members, and polishing methods and polishing apparatuses using the same. In particular, the invention relates to a polishing brush or abrasive member, a polishing method, and a polishing apparatus that are suitable to polish inner peripheries of glass substrates for small-diameter magnetic disks, and to a method of manufacturing a glass substrate for a magnetic disk and a method of manufacturing a magnetic disk.

Background Art

[0002]

As IT industry is rapidly developed, dramatic technological innovation is required of information recording technology, particularly magnetic recording technology. A magnetic disk mounted in an information recording device, such as a hard disk drive (HDD), requires an information recording density of at least 40 to 100 Gbit/inch², responding to the growing demand for high capacity.

[0003]

While substrates for magnetic recording medium, such as magnetic disks, have conventionally been made of an aluminum alloy, glass substrates are being thought of as a magnetic disk substrate suitable to increase the recording density. Glass substrates have a higher stiffness than aluminum alloy substrates, and are accordingly suitable to higher rotation speed of magnetic

disk devices. Also, the glass substrate can have such a smooth surface as the flying height of the magnetic head can easily be reduced. Consequently, the S/N ratio of recording signals can advantageously be increased.

[0004]

In addition, in order to increase the recording density of the magnetic disk, high processing precision is required of the glass substrate, including not only the main surface, but also the shape of the peripheries.

[0005]

Patent Document 1 listed below discloses a method for polishing a periphery of a glass substrate. In the method, a circular glass substrate having a circular hole in the center is immersed in a liquid abrasive containing suspended abrasive grains, and the inner periphery of the glass substrate is polished in the liquid abrasive by rotation with a polishing brush or a polishing pad in contact with the substrate.

[0006]

Fig. 10 is a sectional view of a polishing apparatus illustrating the known polishing method. In Fig. 10, reference numeral 60 designates a glass substrate for a magnetic disk as an object to be polished; 61, a substrate case accommodating many glass substrates 60 immersed in a liquid abrasive; 65, a rotatable support rotatably supporting the substrate case 61; 62, a polishing brush inserted in the hole defined by the inner peripheries of the stack of the many glass substrates 60; and 68, a liquid abrasive container containing a liquid abrasive. The substrate case 61 has a liquid abrasive flow path 70 through which the liquid abrasive flows between the outside and the inside of the case, at an appropriate lower position. The rotatable support 65 is combined with a rotation shaft 66 and is rotated by driving the rotation shaft 66 to rotate in the right and reverse directions with a rotation driving device 67. The polishing brush 62 is connected to the rotation shaft of another rotation driving device 64

for rotation in the right and reverse directions. Also, the polishing apparatus has a cam mechanism (not shown) that presses the bristle 63 of the polishing brush 62 on the inner peripheries of the glass substrates 60 and allows reciprocal movement of the brush along the rotation axis. Conventional polishing is performed using such a polishing apparatus by rotating the rotatable support 65 and the polishing brush 62 in, for example, directions opposite to each other.

[0007]

[Patent Document 1] Japanese Unexamined Patent Application
Publication No. 11-221742

Disclosure of Invention

Problems to be Solved by the Invention

[0008]

As an information-oriented society is growing, demand for low-price magnetic disks having a high recording density is increasingly rising. The peripheries of the magnetic disk are also required to be smoother and to be processed with a higher precision in a shorter time, and subsidiary materials require longer lifetime.

[0009]

In addition, the above-mentioned hard disk drive is increasingly and rapidly spreading in so-called mobile applications, such as cellular phones, personal digital assistances (PDA), and car navigation systems, as well as being mounted in personal computers. Since the space for mounting a hard disk drive is limited for such mobile use, the hard disk drive is required to be small as well as requiring that the magnetic disk have a high shock resistance. Hence, the magnetic disk used in the hard disk drive is also required to be small. Accordingly, magnetic disks are proposed which are smaller than a relatively

small mobile-oriented so-called 2.5-inch disk. These still smaller magnetic disk include a 1.8-inch disk having an outer diameter of 48 mm and an inner diameter of 12 mm, a 1-inch disk having an outer diameter of 27.4 mm and an inner diameter of 7 mm, and a 0.85-inch disk having an outer diameter of 22 mm and an inner diameter of 6 mm.

[0010]

As the diameter of the magnetic disk is reduced, the thickness of the disk substrate is reduced. While a conventional disk substrate has a thickness of, for example, 0.635 mm, a magnetic disk having a reduced diameter is required to have a thickness of 0.581 mm, 0.381 mm or less.

[0011]

The glass substrate for a magnetic disk, which has a reduced diameter and a reduced thickness, requires that its inner periphery be finished in a desired shape and a mirror-smooth state with a superior dimensional precision. In addition, those glass substrates for magnetic disks, which are finished in high quality with small variation among them, are required to be stably mass-producing at a low cost.

[0012]

When many glass substrates for magnetic disks are manufactured by the known polishing method as disclosed in Patent Document 1, unfortunately the resulting glass substrates have large variations in inner periphery shape and dimensional precision, and the inner peripheries cannot be finished in a highly smooth state. Some defective substrates may be reworked, but the others must be disposed of. Consequently, the cost is undesirably increased.

[0013]

Accordingly, an object of the present invention is to provide a polishing brush or abrasive member, a polishing method and a polishing apparatus that can efficiently finish, particularly, the inner periphery of a glass substrate for a

magnetic disk into a high-quality state at a low cost, from the viewpoint of responding to the demands for magnetic disks, whose diameter is required to be reduced with a high priority, to increase the recording density and reduce the cost. Another object of the invention is to provide a method of manufacturing a glass substrate for a magnetic disk and a method of manufacturing a magnetic disk that include a polishing step using the polishing method to prevent problems resulting from a surface state of the inner periphery of the substrate, and that thus can achieve a high recording density.

Means for Solving the Problems

[0014]

The inventors of the present invention have found that when the inner periphery of a glass substrate having a peripheral wall perpendicular to the main surfaces and two chamfers (intermediate faces) formed between the peripheral wall and the front and rear main surfaces is processed by the known polishing method, both or either of the two chamfers does not finish in an appropriate shape, and that it is difficult to finish the periphery in a highly smooth state. The present inventors have also found that those problems are noticeable in glass substrates having smaller inner diameters. Furthermore, the inventors found that when many glass substrates are stacked and are simultaneously polished, the inner peripheries have large variations in surface state among the substrates.

[0015]

The polishing brush used in the known polishing method as shown in Fig. 10 has a structure in which a bristle called a channel brush prepared by arranging a plurality of bristle materials in parallel and folded at the center and pinching the folded portion by a long metal member is wound around a round (cylindrical) axis and welded. Since the axis requires such a stiffness that the

channel brush can be wound around, the diameter of the axis cannot be reduced much. Accordingly, to polish a glass substrate having a small inner diameter, the length of the bristle must be reduced and the elastic force of the bristle is reduced. Thus, it becomes difficult to finish the periphery in a highly smooth state. In particular, the polishing brush cannot work effectively on a glass substrate having an inner diameter of about 6 to 7 mm. In addition, the known polishing brush has a constant outer diameter in the axis direction. If the polishing brush has a larger diameter than the inner diameter of the glass substrate, the polishing brush occupies a larger volume of the hole defining the inner diameter. Accordingly, the abrasive cannot be stably delivered to the periphery even though polishing is performed while the polishing brush is reciprocally moving. Thus, variations in processing quality become liable to occur.

[0016]

The present inventors have conducted intensive research on the basis of the above-described findings, and accomplished the invention.

[0017]

The present invention has the following features to overcome the above-described problems.

[0018]

(Structure 1) A polishing brush used in a polishing method for polishing the inner periphery of a circular glass substrate having a circular hole in the center thereof by rotating the polishing brush in contact with the inner periphery of the glass substrate while a liquid abrasive is being supplied to the periphery, wherein the polishing brush includes an axis and bristle materials protruding in the direction perpendicular to the axis and defining two types of portions having different outer diameters including a small diameter portion and a large diameter portion, and the bristle materials of the small diameter portion have a

higher hardness than the bristle materials of the large diameter portions.

[0019]

(Structure 2) The polishing brush according to structure 1, wherein the bristle materials of the small diameter portion are hardened by a resin.

[0020]

(Structure 3) A polishing method for polishing the inner periphery of a circular glass substrate having a circular hole in the center thereof, the polishing method comprising preparing a polishing brush including portions having bristle materials arranged along an axis direction and protruded to be different in outer dimension, the bristle materials of a small-diameter portion having a higher hardness than the bristle materials of a large-diameter portion; and substantially vertically inserting the polishing brush into the circular hole, and polishing the inner periphery of the glass substrate by making the polishing brush relatively move with respect to the inner periphery and by rotating the polishing brush in contact with the inner periphery while a liquid abrasive is delivered to the inner periphery.

[0021]

(Structure 4) The polishing method according to structure 3, wherein polishing is performed in such a manner that a plurality of glass substrates are stacked one on top of another so that the inner peripheries of the glass substrates are simultaneously polished.

[0022]

(Structure 5) The polishing method according to structure 3 or 4, wherein the circular hole in the center of the glass substrate has a diameter of 12 mm or less.

[0023]

(Structure 6) A polishing apparatus comprising a substrate cassette holding means that holds a substrate cassette accommodating a plurality of

circular glass substrates stacked one on top of another, the glass substrates each having a circular hole in the center thereof; a liquid abrasive delivering means that delivers a liquid abrasive to the inner peripheries of the stack of the glass substrates accommodated in the substrate cassette; a polishing brush held for rotation and contact with the inner peripheries of the glass substrates within the substrate cassette; a first driving means that drives the polishing brush for rotation; and a second driving means that relatively moves the polishing brush with respect to the inner peripheries of the stack of the glass substrates in the substrate cassette, wherein the polishing brush includes portions having bristle materials arranged along an axis direction and protruded to be different in outer dimension and the bristle materials of a small-diameter portion has a higher hardness than the bristle materials of a large diameter portion.

[0024]

(Structure 7) A method of manufacturing a glass substrate for a magnetic disk, comprising the step of polishing the inner periphery of a circular glass substrate having a circular hole in the center thereof by the polishing method as set forth in any one of structures 3 to 5.

[0025]

(Structure 8) A method of manufacturing a magnetic disk, comprising the step of forming at least a magnetic layer on a main surface of a glass substrate for a magnetic disk, which is manufactured by the method set forth in structure 7.

[0026]

(Structure 9) A method of manufacturing a glass substrate for a magnetic disk, comprising the periphery polishing step of polishing both the peripheral wall of a glass substrate and intermediate faces between the main surfaces and the peripheral wall of the glass substrate, the periphery polishing

step being performed using an abrasive member having a peripheral wall-polishing portion mainly polishing the peripheral wall and an intermediate face-polishing portion mainly polishing the intermediate faces while a liquid abrasive containing abrasive grains is delivered to the peripheral wall and the intermediate faces.

[0027]

(Structure 10) The method according to structure 9, wherein the abrasive member has a rotation axis, and the periphery polishing step is performed by rotating the abrasive member with the peripheral wall-polishing portion in contact with the peripheral wall of the glass substrate and/or with the intermediate face-polishing portion in contact with the intermediate faces of the glass substrate.

[0028]

(Structure 11) The method according to structure 10, wherein the length of the abrasive member in the direction perpendicular to the rotation axis from the rotation axis to the peripheral wall-polishing portion is smaller than the length of the abrasive member in the direction perpendicular to the rotation axis from the rotation axis to the intermediate face-polishing portion.

[0029]

(Structure 12) The method according to any one of structures 9 to 11, wherein the abrasive member has a rotation axis, and the section of the abrasive member taken along the plane including the rotation axis has a shape matching the shape of the periphery of a stack of glass substrates.

[0030]

(Structure 13) The method according to any one of structures 9 to 12, wherein the periphery polishing step is performed in such a manner that a plurality of glass substrates are stacked one on top of another so that the inner peripheries of the glass substrate are simultaneously polished.

[0031]

(Structure 14) The method according to any one of structures 9 to 13, wherein the abrasive member has the peripheral wall-polishing portions and the intermediate face-polishing portions alternately arranged in the axis direction.

[0032]

(Structure 15) The method according to any one of structures 9 to 14, wherein the intermediate face-polishing portion is a polishing brush.

[0033]

(Structure 16) The method according to claim 15, wherein the peripheral wall-polishing portion is an abrasive pad.

[0034]

(Structure 17) The method according to any one of structures 9 to 16, wherein the peripheral wall-polishing portion is a polishing brush whose bristles are hardened by a resin.

[0035]

(Structure 18) The method according to any one of structures 9 to 17, wherein the abrasive member has a rotation axis, and the polishing step is performed by retaining the abrasive member and/or moving the abrasive member in the direction of the rotation axis.

[0036]

(Structure 19) An abrasive member used in a method of manufacturing a glass substrate for a magnetic disk, including the step of periphery polishing step of polishing both the peripheral wall of a glass substrate and intermediate faces between the main surfaces and the peripheral wall of the glass substrate, the abrasive member comprising a peripheral wall-polishing portion mainly polishing the peripheral wall; and an intermediate face-polishing portion mainly polishing the intermediate faces.

[0037]

(Structure 20) A polishing apparatus comprising a substrate support means that supports a glass substrate; a liquid abrasive supplying means that supplies a liquid abrasive to the inner periphery of the glass substrate; a abrasive member having a rotation axis and including a peripheral wall-polishing portion mainly polishing the peripheral wall of the glass substrate, and an intermediate face-polishing portion mainly polishing intermediate faces between the main surfaces and the peripheral wall of the glass substrate; and a driving means that rotates the abrasive member and/or moves the abrasive member in the direction of the rotation axis with the abrasive member in contact with the inner periphery of the glass substrate.

[0038]

(Structure 21) The polishing apparatus according to claim 20, wherein the abrasive member is rotated with the peripheral wall-polishing portion in contact with the peripheral wall of the glass substrate and/or with the intermediate face-polishing portion in contact with the intermediate faces of the glass substrate.

Advantages

[0039]

According to the polishing brush (abrasive member), the polishing method and polishing apparatus using the polishing brush (abrasive member), even the inner periphery of a substrate having a small inner diameter of, for example, 12 mm or less can be finished in a desired shape and a mirror-smooth state with a high dimensional precision. In addition, even though the inner peripheries of many glass substrates stacked one on top of another are simultaneously polished, the variation in finished state is reduced among the substrates, and, thus, glass substrates for magnetic disks, which are finished in high quality, can be stably mass-produced at a low cost.

[0040]

According to the method of manufacturing a glass substrate for a magnetic disk and a method of manufacturing a magnetic disk, including a polishing step using the polishing method, even the inner periphery of a substrate having a small inner diameter of, for example, 12 mm or less can be finished in high quality. Also, the methods can prevent problems resulting from a surface state of the inner periphery, and the resulting glass substrate and magnetic disk can achieve high recording densities.

Brief Description of Drawings

[0041]

Fig. 1 is a perspective view of the entirety of a glass substrate for a magnetic disk, which has a circular hole in the center.

Fig. 2 is a sectional view illustrating the shape of the inner periphery of the glass substrate.

Fig. 3 is a sectional view of a polishing brush according to an embodiment of the present invention.

Fig. 4 is a sectional view of a guide used for placing glass substrates in a substrate cassette so as to be stacked in the axis direction with the centers of the inner diameters aligned.

Fig. 5 is a sectional view of the state in which the glass substrates are accommodated in the substrate cassette so as to be stacked in the axis direction with the centers of the inner diameters aligned.

Fig. 6 is a sectional view of the state in which the substrate cassette containing the stack of glass substrates is placed in a polishing apparatus.

Fig. 7 is a side sectional view of the structure of a polishing apparatus according to an embodiment of the present invention.

Fig. 8 is a schematic sectional view of the structure of a magnetic disk

according to the present invention.

Fig. 9 is a sectional of a polishing brush according to another embodiment of the present invention.

Fig. 10 is a sectional view of a polishing apparatus illustrating the known polishing method.

Reference Numerals

[0042]

- 1 glass substrate
- 10 magnetic disk
- 11 main surface of glass substrate
- 12 inner periphery of glass substrate
- 20, 25 polishing brush
- 22 bristle material
- 34 substrate cassette
- 40 polishing apparatus

Best Modes for Carrying Out the Invention

[0043]

Best modes of the present invention will now be described in detail.

[0044]

Fig. 1 is a perspective view of the entirety of a magnetic disk glass substrate (glass substrate for a magnetic disk) 1 used in the present invention. The glass substrate 1 is a disk having a circular hole in the center, and has a front and a rear main surface 11, and an inner periphery 12 and an outer periphery 13 formed between the main surfaces 11.

[0045]

Fig. 2 is a sectional view illustrating the shape of the inner periphery 12 of

the magnetic disk glass substrate 1. As shown in Fig. 2, the inner periphery 12 of the glass substrate 1 has a peripheral wall 12a perpendicular to the main surfaces 11 and two chamfers (chamfered faces) 12b formed between the peripheral wall 12a and the front and rear main surfaces 11. The inner periphery 12 may not be chamfered between the peripheral wall 12a and the front and rear main surfaces 11. Faces formed between the peripheral wall 12a and the front and rear main surfaces 11 are herein referred to as "intermediate faces", and the intermediate faces may be the chamfers as shown in Fig. 2.

[0046]

The magnetic disk glass substrate is finished into a small-diameter magnetic disk having, for example, an outer diameter of 48 mm and an inner diameter of 12 mm for a 1.8-inch disk, an outer diameter of 27.4 mm and an inner diameter of 7 mm for a 1-inch disk, and an outer diameter of 22 mm and an inner diameter of 6 mm for a 0.85-inch disk. The inner diameter mentioned herein refers to the diameter of the circular hole formed in the center of the glass substrate 1.

[0047]

As the diameter of the magnetic disk is reduced, the thickness of the disk substrate is also reduced. For example, while the disk substrate of the conventional 2.5-inch disk has a thickness of 0.635 mm, the thickness of the substrate for a smaller-diameter magnetic disk is reduced to 0.581 mm, 0.381 mm or less.

[0048]

The main surfaces 11, the inner periphery 12, and the outer periphery 13 of the magnetic disk glass substrate 1 are polished (mirror-polished) to have predetermined surface roughnesses, respectively. The inner periphery 12 is required to be finished into the above-described shape and in a mirror-smooth

state having a surface roughness of, for example, 0.10 nm or less in terms of Ra.

[0049]

Fig. 3 is a sectional view illustrating the structure of a polishing brush according to an embodiment of the present invention.

[0050]

The polishing brush of the present invention is used in the polishing method for polishing a circular magnetic disk glass substrate having a circular hole in the center. In the polishing method, the polishing brush is brought into contact with the inner periphery of the glass substrate and rotated to polish the substrate while a liquid abrasive is delivered to the inner periphery. The polishing brush 20 according to an embodiment of the invention includes an axis 21 and bristle materials 22 protruding from the axis 21 in the direction substantially perpendicular to the axis 21, as shown in Fig. 3. Two types of portions having different diameters (D1, D2) are alternately arranged over the length of the axis. The bristle materials of the portions having a small diameter (D2) have a higher hardness than the portions having a large diameter (D1). By polishing the inner periphery of the glass substrate with such a polishing brush, the inner periphery can be appropriately finished into a predetermined shape with a high dimensional precision and in a mirror-smooth state having a surface roughness of, for example, 0.10 nm or less in terms of Ra, even if the substrate has a small diameter of 12 mm or less.

[0051]

Preferably, the axis 21 of the polishing brush 20 includes a plurality of stainless steel core wires having a diameter of several millimeters, and the core wires are twined so as to be twisted around each other. The axis having such a structure can be thin as much as possible, and can be used for a disk substrate having an inner diameter of 6 to 7 mm. In addition, a minimum

stiffness required for the polishing brush can be ensured. The polishing brush of the present invention may be manufactured by twining the plurality of core wires with the bristle materials pinched between the core wires. In this instance, the bristle materials may have different lengths for the portions having different diameters, or bristle materials having the same length may be used to form a brush, and are then appropriately cut to adjust the diameters.

[0052]

The bristle materials 22 are generally and preferably made of nylon fiber, and may be made of polyester fiber, polypropylene fiber, vinyl chloride fiber, boar bristle, piano wire, or stainless fiber, instead of the nylon fiber. From the viewpoint of elasticity, preventing the reduction of the mechanical strength under moist conditions, and durability, nylon fiber is suitable. Among nylon fibers preferred are water-resistant nylons, such as 66 nylon and 610 nylon. A fiber of the bristle material preferably has a diameter of about 0.05 to 0.15 mm. An abrasive-containing nylon fiber may be used.

[0053]

The polishing brush having the alternately arranged two portions having different diameters can appropriately polish both the peripheral wall 12a and the chamfers 12b of the inner periphery 12 of the glass substrate 1. More specifically, the large-diameter portions having a first outer diameter (D1) suitably polish and finish the chamfers 12b into an appropriate shape and in a mirror-smooth state, and small-diameter portions having a second outer diameter (D2) suitably polish and finish the peripheral wall 12a into an appropriate shape and in a mirror-smooth state (functioning as a polishing pad). The first and second outer diameters depend on the size of the disk substrate, but the first outer diameter D1 is preferably 1 to 5 mm larger than the inner diameter (final diameter) of the glass substrate 1, that is, the inner diameter of the circular hole in the center of the glass substrate 1. Also, the second outer

diameter is preferably substantially the same as the inner diameter of the glass substrate 1 (slightly larger than the inner diameter of the glass substrate).

[0054]

In other words, the portions of the polishing brush having outer diameter D1 for polishing the chamfers (intermediate faces) have such a diameter as can reach the chamfers (closer to the main surfaces) of the periphery of the glass substrate, and the portions having outer diameter D2 for polishing the peripheral wall have a larger diameter than the inner diameter of the glass substrate and a smaller diameter than outer diameter D1 so as to polish the peripheral wall of the glass substrate with reliability.

[0055]

In the present embodiment, the two types of portions having different outer diameters (D1, D2) are alternately arranged over the length in the axis direction. The length L1 of the portions having the first outer diameter D1 and the length L2 of the portions having the second outer diameter D2 depend on the size of the disk substrate, but are preferably, for example, about 3 mm each for a glass substrate having an inner diameter of 7 mm.

[0056]

As described above, the polishing brush of the present embodiment is an abrasive member having both a peripheral wall-polishing portion for mainly polishing the peripheral wall of the inner periphery of the glass substrate 1 (the small-diameter portion having the second outer diameter D2 in the present embodiment) and an intermediate face-polishing portion for mainly polishing the intermediate faces formed between the main surfaces of the glass substrate 1 and the peripheral wall (the large-diameter portion having the first outer diameter D1 in the present embodiment). Although the peripheral wall-polishing portion is intended to polish the peripheral wall and mainly polishes the peripheral wall, this portion may polish the intermediate faces in addition to

the peripheral wall. Although the intermediate face-polishing portion is intended to polish the intermediate faces and mainly polishes the intermediate faces, this portion may polish the peripheral wall in addition to the intermediate faces.

[0057]

The use of the polishing brush (abrasive member) allows the simultaneous polishing of the peripheral wall and the intermediate faces of the inner periphery of the glass substrate, and these faces can be polished with a high precision. In addition, the polishing brush can appropriately polish the inner periphery of the magnetic disk glass substrate that is difficult to polish with a polishing brush having the known structure. As described above, hard disk drives (HDD) are rapidly spread in mobile use (portable use), and the size of the HDD is required to be small. Accordingly, the magnetic disk mounted in the HDD is also required to be small, and downsizing the magnetic disk so as to be suitable for mobile use is an urgent necessity. In general, the precision in processing the inner periphery of a glass substrate is lower than the precision in metal-processing the spindle motor of a HDD. In particular, in a HDD in mobile use, an impact during operation may cause misalignment, and the head may deviate to another track to cause an error when the head reads written data. It is therefore significantly important to increase the processing precision of the inner periphery of a small-diameter magnetic disk used in, particularly, a HDD for mobile use, even though the inner diameter of the magnetic disk is reduced as the diameter of the magnetic disk is reduced. The polishing method using the polishing brush (abrasive member) of the present invention can highly precisely polish the inner periphery of the small-diameter magnetic disk glass substrate and allows the ID tolerance to be reduced. Accordingly, the glass substrate can be precisely clamped to the spindle motor, and thus the above-described error can be reduced.

[0058]

In the polishing brush of the present embodiment, the bristle materials of the portions having a small diameter (D2) have a higher hardness than that of the portions having a large diameter (D1). If the hardness of the bristle materials of the portions having a small diameter (D2) is insufficient, those portions cannot appropriately produce the effect of mainly polishing the peripheral wall 12a (function as polishing pad), and thus the periphery may result in an undesired shape.

[0059]

In order for the portions having a small diameter (D2) of the polishing brush to have a higher hardness than the portions having a large diameter (D1), preferably, the bristle materials of the small-diameter portions of the polishing brush may be impregnated with a resin and thus bound together. The resin is preferably a rubber adhesive having a resistance to water and an appropriate hardness. Examples of such resins include epoxy resins and acrylic resins. The hardness of the portions having a small diameter (D2) can be appropriately adjusted as required. In the polishing brush of the present embodiment, the bristle materials of the portions having a small diameter (D2) have a higher hardness than that of the portions having a large diameter (D1), and a high hardness means a high stiffness or high elastic modulus. "Higher hardness" mentioned herein means that the stiffness is set higher, or that the elastic modulus is set higher.

[0060]

In order to give different hardnesses (elastic moduli) to the small-diameter portions and the large-diameter portions, the polishing brush may use bristle materials having different hardnesses.

[0061]

While the polishing brush shown in Fig. 3 as an embodiment of the

invention includes two types of portions having different diameters (D1, D2) alternately arranged over the length in the axis direction, the polishing brush of the present invention is not limited to such an embodiment, as long as two types of portions having different diameters are arranged. For example, the portion having a large diameter (D1) may be disposed over the left half of the axis and the portion having a small diameter (D2) is disposed over the right half. Thus, the two portions may be separately arranged. Alternatively, the portions having different diameters may be alternately or separately arranged along the periphery of the polishing brush (the cross section of the axis has portions having different diameters in the radius direction).

[0062]

Fig. 9 is a sectional view of a polishing brush according to another embodiment of the present invention. The polishing brush 25 shown in Fig. 9 is the same as the polishing brush shown in Fig. 3 in that it has both peripheral wall-polishing portions 24 (small-diameter portions having outer diameter D2 of the present embodiment) and intermediate face-polishing portions 23 (large-diameter portions having outer diameter D1). However, the polishing brush 25 of the present embodiment is featured in that the section of the intermediate face-polishing portions 23 taken along a plane including the rotation axis of the polishing brush has an angular shape. The section (Fig. 9) of the entire polishing brush 25 taken along the plane including the rotation axis of the polishing brush has a shape that fits with the shape formed by the peripheries of the glass substrates stacked one on top of another. Thus, the polishing brush appropriately polishes the peripheries of the stacked glass substrates in such a manner that the brush favorably comes into contact (or is pressed on) along the peripheries.

[0063]

The polishing brush of the present invention has both a peripheral wall-

polishing portion and an intermediate face-polishing portion, and may have a structure including a bristle material portion and a pad portion. For example, the peripheral wall-polishing portion may be a polishing pad, and the intermediate face-polishing portion may be a polishing brush. In this instance, the pad portion may be made of the same material as the polishing pad used for mirror-polishing the main surfaces of the glass substrate (for example, soft pad such as a suede pad or hard pad such as foamed urethane resin).

[0064]

The polishing method of the present invention polishes the inner periphery of a circular glass substrate having a circular hole in the center. In the polishing method, the polishing brush of the present invention is substantially vertically inserted in the circular hole, and polishes the inner periphery 12 of the glass substrate 1 by relatively displacing the polishing brush in the direction along the rotation axis and rotating the polishing brush in contact with the inner periphery while a liquid abrasive is delivered to the inner periphery of the glass substrate.

[0065]

The polishing method of the present invention is suitable to simultaneously polish the inner peripheries of a plurality of glass substrates stacked one on top of another. Specifically, the polishing method can finish the inner peripheries even of small-diameter substrates having an inner diameter of, for example, 12 mm or less into a desired shape with a high precision, and in a mirror-smooth state having a surface roughness of, for example, 0.10 nm or less in terms of Ra. Furthermore, the variation among the substrates can be reduced, and thus, magnetic disk glass substrates finished in high quality can be mass-produced at a low cost.

[0066]

The polishing method of the present invention is suitable for small-

diameter glass substrates having a hole of 12 mm in diameter in the center. Specifically, the polishing method can finish the inner periphery of the disk substrate into a desired shape with a high precision and in a mirror-smooth state having a surface roughness of, for example, 0.10 nm or less in terms of Ra even though the inner diameter of the disk substrate is reduced in association with the reduction of the diameter of the magnetic disk.

[0067]

The polishing method may use two types of polishing brushes having different outer diameters (each polishing brush having a constant outer diameter) together in the hole of the substrate instead of the polishing brush of the above embodiment. The rotation speed of each polishing brush and the pressure on the inner periphery of the substrate are appropriately adjusted for polishing. In such a polishing method, the large-diameter polishing brush mainly polishes and finishes the chamfers of the inner periphery into an appropriate shape and in a mirror-smooth state, and the small-diameter polishing brush mainly polishes and finishes the peripheral wall of the inner periphery into an appropriate shape and in a mirror-smooth state (functioning as a polishing pad). Thus, both the peripheral wall and the chamfers of the inner periphery of the glass substrate can be favorably polished.

[0068]

A polishing apparatus according to the present invention will now be described.

[0069]

Fig. 4 is a sectional view of a guide used for placing glass substrates in a substrate cassette so as to be stacked in the axis direction with the centers of the inner diameters aligned. Fig. 5 is a sectional view of the state in which the glass substrates are accommodated in the substrate cassette so as to be stacked in the axis direction with the centers of the inner diameters of the

substrates aligned. Fig. 6 is a sectional view of the state in which the substrate cassette accommodating the stack of the glass substrates is placed in the polishing apparatus. Fig. 7 is a side sectional view of the structure of a polishing apparatus according to an embodiment of the present invention.

[0070]

In Fig. 4, a lid 31 is intended to secure the stack of the glass substrates accommodated in the substrate cassette 34. The lid 31 has a circular hole 31a in the center through which the polishing brush is inserted into the cassette placed in the polishing apparatus. Spacers 32 and 33 are intended to protect the stack of the glass substrates accommodated in the substrate cassette 34, and are formed in a disk shape as a whole. The spacers 32 and 33 also have in their centers circular holes 32a and 33a respectively through which the polishing brush is inserted into the cassette placed in the polishing apparatus. The substrate cassette 34 has a cylindrical shape as a whole, and has an opening 34a at the top through which a glass substrate in a disk shape is introduced. The bottom of the substrate cassette 34 has a circular hole 34b through which the stem 35 of a substrate alignment guide 36 is inserted for placing the substrates in the cassette, and through which the polishing brush is inserted when the cassette 34 is put in the polishing apparatus. The substrate alignment guide 36 has a vertical stem 35 in the center that is to be inserted through the circular holes in the center of the glass substrates.

[0071]

In this structure, the substrate cassette 34 is set from above along the stem 35 of the substrate alignment guide 36, and the spacer 33 is first placed in the substrate cassette 34. Then, a stack 30 of, for example, 100 glass substrates is placed in the substrate cassette 34. The glass substrates may of course be placed one by one or by some pieces. The other spacer 32 is set on the glass substrates in the substrate cassette 34 and the lid 81 is further set.

Thus, the accommodation of the glass substrates in the substrate cassette is completed (see Fig. 5). By use of the substrate cassette 34 and the substrate alignment guide 36, anyone can easily place a stack of glass substrates in the substrate cassette at a short time, with the centers of the inner diameters aligned in the axis direction. The substrate cassette containing the glass substrates is further secured at the ends with pushers 47 and 48 of the polishing apparatus (see Fig. 6), and thus can be placed in the polishing apparatus as it is. Hence, the plurality of (many) glass substrates stacked in the axis direction with the centers of the inner diameters aligned are subjected to polishing as they are without being unpiled. Consequently, the variation in roundness or cylindricity can be reduced in a batch and among batches.

[0072]

The polishing apparatus shown in Fig. 7 will now be described.

[0073]

The polishing apparatus has a structure that can receive the substrate cassette 34 containing a plurality of magnetic disk glass substrates 1 to be polished as it is. The substrate cassette 34 can accommodate, for example, about 50, 100, or 200 glass substrates at one time. The substrate cassette 34 is secured in the polishing apparatus by tightening pushers (pressing cocks) 47 and 48 from the axis direction.

[0074]

The substrate cassette 34 is supported for rotation on the axis on the rotatable support 41 of the polishing apparatus 40 with housings 44 and 45. The substrate cassette 34 is rotated on the axis at a predetermined rotation speed by a driving motor (not shown). The housings 44 and 45 are supported by a linear-motion guide for reciprocal movement in the axis direction of the substrate cassette 34 as indicated by arrow A shown in Fig. 7. In the figure, reference numeral 46 designates a bearing. The substrate cassette 34 is

operated for periodical reciprocal movement in the axis direction of the substrate cassette 34 by the driving motor 42 and the cam mechanism 43.

[0075]

The polishing apparatus 40 rotates the polishing brush 20 of the present invention inserted in the center holes of the glass substrates 30 contained in the substrate cassette 34, using the driving motor (not shown) with a brush rotation driving motor shaft 49. The polishing apparatus 40 can rotate the polishing brush 20 in either direction. The rotation speed of the polishing brush 20 can varied between a low level (about 4000 rpm) and a high level (7000 rpm or more). As the inner diameter of the glass substrate is reduced, the polishing brush 20 is required to have a small outer diameter. Accordingly, holding portions are provided at both ends to hold the brush so as to reduce the influence of the reduced stiffness of the brush. In addition to holding the polishing brush 20 at both ends, the apparatus 40 has a mechanism in which an air cylinder 50 presses the brush holding portions outward in the direction parallel to the brush axis to prevent the deviation of the brush axis during working. The polishing apparatus 40 is variable independently in rotation speed of the polishing brush, rotation speed of the substrate cassette, speed and width of the reciprocal movement of the substrate cassette, pressure of the polishing brush on the inner periphery of the substrate.

[0076]

Preferably, a liquid abrasive is delivered to the inner periphery of the stack of the glass substrates 1 during polishing. In order to deliver the liquid abrasive, a liquid abrasive delivering portion (not shown) delivers the liquid abrasive through a slurry pipe 51 or 53 in the structure shown in Fig. 7. For delivering the liquid abrasive, a switching solenoid 52 or 54 switches the direction of the liquid abrasive flow from the downward direction to the upward direction and vice versa. In order to prevent the change in fluidity of the

abrasive with time, a function may be provided to flush the liquid abrasive flow channels with tap water after polishing.

[0077]

Abrasives used herein include cerium oxide, iron oxide, magnesium oxide, zirconium oxide, and manganese oxide. Cerium oxide is particularly suitable because of its hardness close to the hardness of the glass substrate 1. An excessively hard abrasive scratches the periphery of the glass substrate, and an excessively soft abrasive cannot polish the periphery of the glass substrate in a mirror state. The temperature of the liquid abrasive is preferably about 25 to 40 °C.

[0078]

The above-described polishing apparatus using the polishing brush of the present invention can finish the inner periphery even of a small-diameter substrate having a diameter of, for example, 12 mm or less into a desired shape with an appropriate dimensional precision and in a mirror-smooth state having a surface roughness of, for example, 0.10 nm or less in terms of Ra.

Furthermore, the resulting magnetic disk glass substrates have low variations among them. Such high quality substrates can be mass-produced at a low cost with reliability. Since the polishing brush of the present invention has portions having different outer diameters, the liquid abrasive can sufficiently be delivered to the inner periphery of the substrate even though the large-diameter portion has an outer diameter larger than the inner diameter of the substrate.

[0079]

Since the polishing apparatus of the present invention can receive the substrate cassette as it is, the glass substrates stacked and accommodated in the substrate cassette with the centers of the inner diameters aligned in the axis direction can be subjected to polishing as they were without being unpiled. Consequently, the variation in roundness or cylindricity can be reduced in a

batch and among batches.

[0080]

The polishing apparatus of the present invention can reduce the amount of the liquid abrasive used in comparison with the known method polishing the glass substrates immersed in a liquid abrasive. Accordingly, the liquid abrasive reservoir can be small and, thus, the space for installing the polishing apparatus can be reduced. In addition, use of a small amount of liquid abrasive leads to a reduced environmental load and is thus environment-oriented.

[0081]

A method of manufacturing a magnetic disk glass substrate according to the present invention includes the step of polishing the inner periphery of a glass substrate by the above-described polishing method of the present invention.

[0082]

A magnetic disk glass substrate is generally manufactured by performing some steps on a glass substrate formed into a disk step by step, including grinding, polishing, and chemically strengthening, and optionally texturing for giving magnetic anisotropy to a magnetic layer. The polishing step includes polishing the periphery of the glass substrate and polishing the main surfaces of the glass substrate.

[0083]

The glass material of the magnetic disk glass substrate is not particularly limited. Examples of the material of the glass substrate include aluminosilicate glass, soda-lime glass, soda-aluminosilicate glass, aluminoborosilicate glass, borosilicate glass, quartz glass, chain silicate glass, and glass ceramics or crystallized glass. Aluminosilicate glass is particularly suitable because of its high impact resistance and vibration resistance. For example, a preferred

aluminosilicate glass is a chemical strengthening glass mainly containing 62% to 75% by weight of SiO_2 , 5% to 15% by weight of Al_2O_3 , 4% to 10% by weight of Li_2O , 4% to 12% by weight of Na_2O , and 5.5% to 15% by weight of ZrO_2 with a $\text{Na}_2\text{O}/\text{ZrO}_2$ weight ratio of 0.5 to 2.0 and a $\text{Al}_2\text{O}_3/\text{ZrO}_2$ weight ratio of 0.4 to 2.5. In order to eliminate protrusions from the surface of the glass substrate caused by undissolved ZrO_2 , the glass may contain 57% to 74% of SiO_2 , 0 to 2.8% of ZnO_2 , 3% to 15% of Al_2O_3 , 7% to 16% of LiO_2 , and 4% to 14% of Na_2O on a mole percent basis.

[0084]

Such aluminosilicate glass can be chemically strengthened to form a compressive stress layer at the surface of the glass substrate and is superior in flexural strength, stiffness, impact resistance, vibration resistance, and heat resistance. Also, the aluminosilicate glass does not separate Na out even in a high temperature environment, can maintain the evenness, and is superior in Knoop hardness. The method for chemical strengthening is not particularly limited as long as a known chemical strengthening is applied. The chemical strengthening of the glass substrate is performed by immersing the glass substrate in a heated chemically strengthening molten salt to exchange the ions at the surface of the glass substrate for ions in the chemically strengthening molten salt.

[0085]

When a chemical strengthening glass substrate is used as the glass substrate, texturing is preferably performed after chemical strengthening. Chemical strengthening may disturb the surface state of the glass substrate during ion exchange.

[0086]

While the diameter of the glass substrate is not particularly limited, the invention is useful and suitable in practice for small magnetic disks, such as 1.8-

inch disk or smaller often used in mobile HDD's, because the present invention provides an impact-resistant magnetic disk glass substrate capable of achieving a high information recording density.

[0087]

The glass substrate preferably has a thickness of about 0.1 to 1.0 mm. For a magnetic disk made of a thin substrate of about 0.6 mm or less, in particular, the inner periphery must be finished in a mirror state to increase the impact resistance, because the inner periphery having a large surface roughness may be cracked to cause dust by contact with the spindle in use in a magnetic disk device. The present invention providing a highly impact-resistant magnetic disk glass substrate having an inner periphery finished in a mirror-smooth state is useful and suitable for a thin magnetic disk glass substrate.

[0088]

A magnetic disk is produced by forming at least a magnetic layer on the magnetic disk glass substrate produced according to the present invention. In general, the magnetic disk preferably has a seed layer, a base layer, a magnetic layer, a protective layer, and a lubricating layer on the glass substrate.

[0089]

The seed layer can be made of alloys having a bcc or a B2 crystal structure, such as Al alloys, Cr alloys, NiAl alloys, NiAlB alloys, AlRu alloys, AlRuB alloys, AlCo alloys, and FeAl alloys, from the viewpoint of reducing the size of the magnetic particles.

[0090]

The base layer may be made of Cr alloys, CrMo alloys, CrV alloys, CrW alloys, CrTi alloys, and Ti alloys to adjust the orientation of the magnetic layer.

[0091]

The magnetic layer may be made of an alloy having an hcp crystal

structure, such as a Co alloy.

[0092]

The protective layer is preferably made of a carbon-based material. The lubricant forming the lubricating layer on the protective layer may be a PFPE (perfluoropolyether) compound. Each layer can be formed on the glass substrate by a known method, such as sputtering.

Example

[0093]

The embodiments of the present invention will be further described in detail with reference to the following Example. The present invention is not limited to the following Example.

[0094]

Example 1

A magnetic disk glass substrate of the present example was prepared through the following steps: (1) rough lapping step (rough grinding step); (2) shaping step; (3) fine lapping step (fine grinding step); (4) periphery polishing step; (5) first main surface polishing step; (6) second main surface polishing step; and (7) chemical strengthening step.

[0095]

(1) Rough lapping step

First, a circular aluminosilicate glass substrate having a diameter of 50 mm and a thickness of 1.0 mm was prepared from a molten glass by direct press using a cope, a drag, and a frame. Alternatively, a sheet glass may be cut into a disk of the glass substrate with grindstone by a down draw method or a float method instead of applying direct press. The aluminosilicate glass was a chemical strengthening glass containing 58% to 75% by weight of SiO_2 , 5% to 23% by weight of Al_2O_3 , 3% to 10% by weight of Li_2O , and 4% to 13% by weight

of Na_2O . Then, the glass substrate was subjected to a lapping step to increase the dimensional precision and form precision. The lapping step was performed with a two-side lapping apparatus and #400 abrasive grains. More specifically, both surfaces of the glass substrate accommodated in a carrier was lapped to a profile irregularity of 0 to 1 μm and a surface roughness (R_{max}) of about 6 μm at a load of about 100 kg with #400 alumina abrasive grains by rotating a sun gear and an internal gear of the lapping apparatus.

[0096]

(2) Shaping step

Then, using a cylindrical grindstone, a hole was formed in the center of the glass substrate and the outer periphery was polished to a diameter of 48 mm. Subsequently, predetermined chamfers were formed at the outer periphery and the inner periphery. At this point, the surface roughnesses of the peripheries of the glass substrate were about 4 μm in terms of R_{max} . In general, a 1.8-inch HDD (hard disk drive) uses a magnetic disk having an outer diameter of 48 mm.

[0097]

(3) Fine lapping step

Then, the surfaces of the glass substrate were lapped with #1000 abrasive grains to a surface roughness of about 2 μm in terms of R_{max} , and about 0.2 μm in terms of R_a . After the lapping step, the glass substrate was immersed in cleaning baths (to which ultrasonic waves were applied) of a neutral detergent and water in that order for ultrasonic cleaning.

[0098]

(4) Periphery polishing step

Then, the outer periphery of the glass substrate was polished with a known polishing brush and a known polishing apparatus. For this polishing, the bristle of the polishing brush was made of 6-6 nylon. The polishing brush

was rotated at a 1400 rpm and a stack of many glass substrates was rotated in the opposite direction to the polishing brush at 60 rpm. A cerium oxide abrasive was used. A liquid abrasive containing the cerium oxide of about 30 °C was delivered during polishing. The polishing time was about 30 minutes.

[0099]

Then, the inner periphery of the glass substrate was polished with the polishing apparatus shown in Fig. 7. A polishing brush having the structure shown in Fig. 3 was used. The polishing brush had outer diameter D1 of 14 mm and outer diameter D2 of 12 mm, and L1 and L2 were 3 mm each. The bristle material was made of 6-6 nylon. The bristle materials of the portions having small diameter D2 were bound together with an epoxy resin. The polishing brush was rotated at 1800 to 2700 rpm (preferably 2200 to 2400 rpm), and the substrate cassette containing the stack of many glass substrates was rotated in the opposite direction to the polishing brush at 60 rpm. The speed and width of the reciprocal movement of the substrate cassette and pressure of the polishing brush on the inner periphery of the substrate were appropriately adjusted. The abrasive was cerium oxide. A liquid abrasive containing the cerium oxide of about 30 °C was delivered during polishing. The polishing time was about 8 to 16 minutes.

[0100]

Thus the resulting 100 glass substrates after polishing had outer peripheries having surface roughnesses of about 0.1 μm in terms of Ra on average, and inner peripheries having surface roughnesses of about 0.05 μm in terms of Ra on average. The dimensional variation in inner diameter was within 10 μm . The surfaces of the glass substrates subjected to the periphery polishing were washed with water.

[0101]

The polished glass substrate was measured for the shape of the inner

periphery with a contour tracer. As a result, the inner periphery 12 had a shape defined by two chamfers 12b and a peripheral wall 12a between the chamfers, as shown in Fig. 2. The outer periphery had substantially the same shape.

[0102]

(5) First main surface polishing step

In order to remove flaws and distortions remaining after the lapping steps, the first polishing step was performed with a two-side polishing apparatus. In the two-side polishing apparatus, the glass substrate held by a carrier was tightly pinched between an upper and a lower surface plate on which polishing pads were stuck, and the carrier was engaged with a sun gear and an internal gear. The glass substrate was thus compressed between the upper and the lower surface plate. Then, the glass substrate was rotated while a liquid abrasive was delivered between the polishing pads and the polished surfaces of the glass substrate. Thus, the glass substrate revolved between the surface plates and rotated on its axis to polish both surfaces at one time. More specifically, the polishing step was performed using hard polishers (rigid foam urethane) as polishers under conditions using an RO water in which cerium oxide (average particle size: 1.3 μm) was dispersed as a liquid abrasive, at a load of 100 g/cm^2 for 15 minutes. After the first polishing step, the glass substrate was subjected to ultrasonic cleaning by being immersed in cleaning baths of neutral detergent, pure water, pure water, IPA (isopropyl alcohol), and IPA (steam dry) in that order, followed by drying.

[0103]

(6) Second main surface polishing

Then, the second polishing step was performed using the same type of two-side polishing apparatus as used in the first polishing step and soft polishers (suede pads). The second polishing step is intended to reduce the

surface roughness R_a to, for example, about 1.0 to 0.3 μm or less under conditions using RO water in which cerium oxide (average particle size: 0.8 μm) was dispersed as a liquid abrasive, at a load of 100 g/cm^2 for 5 minutes while the flat surfaces produced in the first step were maintained. After the second polishing step, the glass substrate was subjected to ultrasonic cleaning by being immersed in cleaning baths of neutral detergent, pure water, pure water, IPA, and IPA (steam dry) in that order, followed by drying.

[0104]

(7) Chemical strengthening step

After the completion of cleaning, the glass substrate was chemically strengthened. For the chemical strengthening, a chemical strengthening liquid containing potassium nitrate and sodium nitrate was prepared. The chemical strengthening liquid was heated to 380 $^{\circ}\text{C}$, and the glass substrate after the above-described cleaning and drying was immersed in the chemical strengthening liquid for 4 hours, thus chemically strengthened. The chemically strengthened glass substrate was subjected to ultrasonic cleaning by being immersed in cleaning baths of sulfuric acid, neutral detergent, pure water, pure water, IPA, and IPA (steam dry) in that order, followed by drying.

[0105]

After the completion of the above cleansing, the surfaces of the glass substrate were subjected to visual inspection and detailed inspection using reflection, diffusion and transmission of light. As a result, protrusions formed by deposit or defects such as flaws were not found on the surfaces of the glass substrate. The main surfaces of the glass substrate obtained through the above-described steps were measured for surface roughness with an atomic force microscope (AFM). As a result, it was found that the resulting magnetic disk glass substrate had an ultra-smooth surfaces of $R_a = 0.20 \text{ nm}$. Also, the glass substrate was finished to an outer diameter of 48 mm, an inner diameter

of 12 mm, and a thickness of 0.581 mm.

[0106]

About ten thousand magnetic disk glass substrates were produced as described above and subjected to long run test. As a result, 90% or more of the substrates satisfied a predetermined peripheral shape, dimensional precision and surface roughness by the first periphery polishing. The nonconforming substrates were repolished, and most of them conformed to those criteria.

[0107]

A magnetic disk 10 as shown in Fig. 8 was produced by forming a nonmagnetic metal layer 2 including a seed layer 2a and a base layer 2b, a magnetic layer 3, a carbon-based protective layer 4, and a lubricating layer 5 as described below on a main surface of the magnetic disk glass substrate produced above.

[0108]

Specifically, an AlRu alloy seed layer 2a, a CrMo alloy base layer 2b, a CoCrPtB alloy magnetic layer 3, and a carbon-based protective layer 4 were formed in that order on a main surface of the glass substrate with a DC magnetron sputtering apparatus. In addition, an alcohol-modified perfluoropolyether lubricating layer 5 was formed on the carbon-based protective layer 4 by dipping. Thus, the magnetic disk 10 was produced.

[0109]

The resulting magnetic disk was loaded in a load/unload (LUL) HDD (hard disk drive). The magnetic head used a GMR element and had a flying height of 10 nm. Thus, a LUL endurance test was performed by repeating load/unload operation. The magnetic disk of the Example endured a million cycles of the LUL operation without failure.

[0110]

Comparative Example

The comparative example is different from the above-described Example in that the inner peripheries of glass substrates were polished by the known polishing method disclosed in Patent Document 1. More specifically, the polishing brush had a structure in which the above-described channel brush was wound around a metal axis, and had a constant outer diameter of 14 mm. The bristle was made of 6-6 nylon. A stack of 100 glass substrates having the same shape and size as in Example 1 was immersed in a liquid abrasive, and the inner peripheries were thus polished. A cerium oxide abrasive was used as in Example 1, and other polishing conditions were appropriately adjusted.

[0111]

The 100 glass substrates after the completion of polishing had outer peripheries having surface roughnesses of about 0.1 μm on average in terms of Ra. The inner peripheries of the glass substrates had surface roughnesses of about 0.20 μm on average in terms of Ra and dimensional variations as large as about 20 μm .

[0112]

The shape of the inner periphery of the glass substrate after periphery polishing was measured with a contour tracer. As a result, the periphery has two chamfers and a peripheral wall between the chamfers as shown in Fig. 2, but recesses formed by probably unstable pressure of the polishing brush were found particularly in the peripheral wall.

[0113]

In the Comparative Example as well, about ten thousand 1.8-inch magnetic disk glass substrates were produced and subjected to long run test. As a result, 70% or less of the substrates satisfied a predetermined peripheral shape, dimensional precision and surface roughness by the first periphery polishing. While some of the nonconforming substrates could be repolished,

50% of the nonconforming substrates could not be repolished and had to be disposed of because of excessive polishing. Furthermore, the variation was large among the substrates.

[0114]

The polishing brush (abrasive member) of the present invention can be substituted for the known polishing brush 62 used in the known periphery polishing apparatus as shown in Fig. 10. By using the polishing brush (abrasive member) of the present invention in the known periphery polishing apparatus, the effect of the present invention is produced, so that peripheries of magnetic disk glass substrates, particularly small-diameter substrates, can be highly precisely polished effectively.

CLAIMS

1. A polishing brush used in a polishing method for polishing the inner periphery of a circular glass substrate having a circular hole in the center thereof by rotating the polishing brush in contact with the inner periphery of the glass substrate while a liquid abrasive is being supplied to the periphery,

wherein the polishing brush includes an axis and bristle materials protruding in the direction perpendicular to the axis and defining two types of portions having different outer diameters including a small diameter portion and a large diameter portion, and the bristle materials of the small diameter portion have a higher hardness than the bristle materials of the large diameter portions.

2. The polishing brush according to claim 1, wherein the bristle materials of the small diameter portion are hardened by a resin.

3. A polishing method for polishing the inner periphery of a circular glass substrate having a circular hole in the center thereof, the polishing method comprising:

preparing a polishing brush including portions having bristle materials arranged along an axis direction and protruded to be different in outer dimension, the bristle materials of a small-diameter portion having a higher hardness than the bristle materials of a large-diameter portion; and

substantially vertically inserting the polishing brush into the circular hole, and polishing the inner periphery of the glass substrate by making the polishing brush relatively move with respect to the inner periphery and by rotating the polishing brush in contact with the inner periphery while a liquid abrasive is delivered to the inner periphery.

4. The polishing method according to claim 3, wherein polishing is performed in such a manner that a plurality of glass substrates are stacked one on top of another so that the inner peripheries of the glass substrates are simultaneously polished.

5. The polishing method according to claim 3, wherein the circular hole in the center of the glass substrate has a diameter of 12 mm or less.

6. A polishing apparatus comprising: a substrate cassette holding means that holds a substrate cassette accommodating a plurality of circular glass substrates stacked one on top of another, the glass substrates each having a circular hole in the center thereof; a liquid abrasive delivering means that delivers a liquid abrasive to the inner peripheries of the stack of the glass substrates accommodated in the substrate cassette; a polishing brush held for rotation and contact with the inner peripheries of the glass substrates within the substrate cassette; a first driving means that drives the polishing brush for rotation; and a second driving means that relatively moves the polishing brush with respect to the inner peripheries of the stack of the glass substrates in the substrate cassette, wherein the polishing brush includes portions having bristle materials arranged along an axis direction and protruded to be different in outer dimension and the bristle materials of a small-diameter portion has a higher hardness than the bristle materials of a large diameter portion.

7. A method of manufacturing a glass substrate for a magnetic disk, comprising the step of polishing the inner periphery of a circular glass substrate having a circular hole in the center thereof by the polishing method as set forth in claim 3.

8. A method of manufacturing a magnetic disk comprising the step of forming at least a magnetic layer on a main surface of a glass substrate for a magnetic disk, which is manufactured by the method set forth in claim 7.

9. A method of manufacturing a glass substrate for a magnetic disk, comprising the periphery polishing step of polishing both the peripheral wall of a glass substrate and intermediate faces between the main surfaces and the peripheral wall of the glass substrate, the periphery polishing step being performed using an abrasive member having a peripheral wall-polishing portion

mainly polishing the peripheral wall and an intermediate face-polishing portion mainly polishing the intermediate faces while a liquid abrasive containing abrasive grains is delivered to the peripheral wall and the intermediate faces.

10. The method according to claim 9, wherein the abrasive member has a rotation axis, and the periphery polishing step is performed by rotating the abrasive member with the peripheral wall-polishing portion in contact with the peripheral wall of the glass substrate and/or with the intermediate face-polishing portion in contact with the intermediate faces of the glass substrate.

11. The method according to claim 10, wherein the length of the abrasive member in the direction perpendicular to the rotation axis from the rotation axis to the peripheral wall-polishing portion is smaller than the length of the abrasive member in the direction perpendicular to the rotation axis from the rotation axis to the intermediate face-polishing portion.

12. The method according to claim 9, wherein the abrasive member has a rotation axis, and the section of the abrasive member taken along the plane including the rotation axis has a shape matching the shape of the periphery of a stack of glass substrates.

13. The method according to claim 9, wherein the periphery polishing step is performed in such a manner that a plurality of glass substrates are stacked one on top of another so that the inner peripheries of the glass substrate are simultaneously polished.

14. The method according to claim 9, wherein the abrasive member has the peripheral wall-polishing portions and the intermediate face-polishing portions alternately arranged in the axis direction.

15. The method according to claim 9, wherein the intermediate face-polishing portion is a polishing brush.

16. The method according to claim 15, wherein the peripheral wall-polishing portion is an abrasive pad.

17. The method according to claim 9, wherein the peripheral wall-polishing portion is a polishing brush whose bristles are hardened by a resin.

18. The method according to claim 9, wherein the abrasive member has a rotation axis, and the polishing step is performed by retaining the abrasive member and/or moving the abrasive member in the direction of the rotation axis.

19. An abrasive member used in a method of manufacturing a glass substrate for a magnetic disk, including the step of periphery polishing step of polishing both the peripheral wall of a glass substrate and intermediate faces between the main surfaces and the peripheral wall of the glass substrate, the abrasive member comprising:

- a peripheral wall-polishing portion mainly polishing the peripheral wall; and
- an intermediate face-polishing portion mainly polishing the intermediate faces.

20. A polishing apparatus comprising:

- a substrate support means that supports a glass substrate;

- a liquid abrasive supplying means that supplies a liquid abrasive to the inner periphery of the glass substrate;

- a abrasive member having a rotation axis and including a peripheral wall-polishing portion mainly polishing the peripheral wall of the glass substrate, and an intermediate face-polishing portion mainly polishing intermediate faces between the main surfaces and the peripheral wall of the glass substrate; and

- a driving means that rotates the abrasive member and/or moves the abrasive member in the direction of the rotation axis with the abrasive member in contact with the inner periphery of the glass substrate.

21. The polishing apparatus according to claim 20, wherein the abrasive member is rotated with the peripheral wall-polishing portion in contact with the peripheral wall of the glass substrate and/or with the intermediate face-polishing portion in contact with the intermediate faces of the glass substrate.