

DESCRIPTION

METHOD OF MANUFACTURING GLASS SUBSTRATE FOR MAGNETIC DISK
AND METHOD OF MANUFACTURING MAGNETIC DISK

Technical Field

[0001]

The present invention relates to a method of manufacturing a glass substrate for a magnetic disk used as a recording medium of a computer or the like, and a method of manufacturing the magnetic disk.

Background Art

[0002]

Recently, improvement in recording density is increasingly required for a magnetic recording medium. To improve magnetic recording density, for example, flying height of a recording head needs to be reduced. This is because reduction in flying height of a recording head enables reduction in spacing loss, resulting in improvement in recording density.

[0003]

To reduce flying height of a recording head, surface roughness of a magnetic disk as a recording medium needs to be reduced, in addition, an end shape of the magnetic disk needs to be a substantially flat shape, that is, a shape being even compared with a central portion in order to stabilize flying of the recording head. To make the end shape of the magnetic disk to be substantially flat, an end shape of the glass substrate for a magnetic disk needs to be made into a substantially flat shape. Meaning of the end shape is described later.

[0004]

In particular, while a perpendicular magnetic recording method and the like are recently developed to achieve improvement in recording density, if the end shape of the glass substrate for a magnetic disk cannot be kept to be a precisely flat shape without unevenness, the perpendicular magnetic recording method cannot be used, and consequently improvement in recording density cannot be achieved.

[0005]

As a method of manufacturing the glass substrate for a magnetic disk, which prevents disturbance in end shape or the like, for example, Patent Document 1 is proposed in the past.

[0006]

Patent Document 1: JP-A-2005-141852

Disclosure of the Invention

Problems that the Invention is to Solve

[0007]

However, when a recording head is allowed to fly and run with flying height being reduced from, for example, about 10 nm in the past, there has been a problem that flying of a magnetic head is unstable, leading to crush of the recording head. The inventors of the application investigated a cause of crush of a head, as a result, they found that an end shape of a glass substrate, which was not a desired flat shape, was the cause of the crush.

[0008]

Moreover, the inventors of the application investigated a polishing step of the glass substrate, as a result, they found a fact that sufficient flatness to avoid the crush was extremely hardly provided on the end shape in a latter polishing step in the past. Therefore, a measure needs to be taken for making the end shape to be a flat shape compared with a present condition.

[0009]

However, a method of manufacturing a glass substrate for a magnetic disk includes a plurality of processing steps, which may change the end shape of the glass substrate, including a plurality of polishing steps. Therefore, it is restrictive that only one step among the plurality of processing steps is reviewed to form a desired end shape in the light of other requirements to be satisfied (for example, manufacturing conditions such as processing time and a processing condition, cost, and a characteristic value of a surface profile required for a glass substrate).

[0010]

In the light of such problems, an object of the invention is to provide a glass substrate for a magnetic disk having a desired end shape by reviewing a plurality of processing steps including a plurality of polishing steps.

Means for Solving the Problems

[0011]

The inventors of the application found that since an end shape of a glass substrate is changed in each of a plurality of polishing steps, to obtain an end shape to be finally required, shape change characteristics (the amount of change in shape and a changed shape) of an end shape in a preceding polishing step is grasped before the preceding polishing step is performed, and based on the characteristics, shape change characteristics of the end shape in a subsequent polishing step is set, thereby an end shape that enables reduction in flying height of a magnetic head can be obtained, and finally the inventors completed the invention. As an item to be grasped before the preceding polishing step, change in end shape in the subsequent polishing step may be used. In that case, shape change characteristics of the end shape in the preceding polishing step can be set depending on the change in end shape

being previously grasped.

[0012]

Aspects of the invention are listed below.

[0013]

(First aspect)

A method of manufacturing a glass substrate for a magnetic disk including a first treatment step and a second treatment step, in each of which an end shape of the glass substrate is changed, wherein the method includes a grasp step of grasping an end shape of the glass substrate after the first treatment step before the relevant first treatment step is performed, and in the second treatment step, the glass substrate is changed in a direction of cancelling the end shape grasped in the grasp step, so that the end shape is made into a desired shape.

[0014]

The desired shape may be assumed that the end shape of the glass substrate is a substantially flat shape, or may be assumed that the end shape of the glass substrate is a shape being descended compared with a central portion. Specifically, for example, after the first and second treatment steps are carried out, for example, when chemical strengthening treatment is performed, in which the end shape is changed in a rising manner, it is preferable that the end shape of the glass substrate is made to be the shape being descended compared with the central portion at a point when the second treatment step is finished. When a treatment that may change the end shape is not performed after the second treatment step is finished, it is preferable that the end shape of the glass substrate is made to be a substantially flat shape at the point when the second treatment step is finished.

[0015]

(Second aspect)

A method of manufacturing a glass substrate for a magnetic disk including a plurality of polishing steps, in which a polishing liquid containing abrasive grains is supplied between a glass substrate and a polishing pad for polishing a main surface of the glass substrate, and the glass substrate and the polishing pad are relatively moved to each other, thereby the glass substrate is polished, wherein the plurality of polishing steps include a preceding polishing step for performing polishing such that an end shape of the main surface of the glass substrate becomes a shape being protruded (or descended) compared with a central portion of the main surface, and a subsequent polishing step for performing polishing such that the glass substrate is changed in a direction of cancelling the shape being protruded (or descended) in the preceding polishing step so that the end shape is made into a desired shape.

[0016]

(Third aspect)

In the second aspect, (1) when polishing is performed in the preceding polishing step such that the end shape of the main surface of the glass substrate becomes a protruded shape, polishing is performed in the subsequent polishing step such that when a glass substrate of which the end shape is a flat shape is polished, the end shape becomes a shape being descended compared with the central portion; and (2) when polishing is performed in the preceding polishing step such that the end shape of the main surface of the glass substrate becomes a descended shape, polishing is performed in the subsequent polishing step such that when a glass substrate of which the end shape is a flat shape is polished, the end shape becomes a shape being protruded compared with the central portion.

[0017]

(Fourth aspect)

In the second aspect, when polishing is performed in the preceding

polishing step such that the end shape of the main surface of the glass substrate becomes a protruded shape, a polishing pad is used in the subsequent polishing step, which has high hardness compared with a polishing pad used in the preceding polishing step; and when polishing is performed in the preceding polishing step such that the end shape of the main surface of the glass substrate becomes a descended shape, a polishing pad is used in the subsequent polishing step, which has low hardness compared with a polishing pad used in the preceding polishing step.

[0018]

(Fifth aspect)

In the second aspect, polishing is performed in the subsequent polishing step such that roughness (Ra) of the main surface of the glass substrate is 0.2 nm or less after the relevant subsequent polishing step is performed.

[0019]

(Sixth aspect)

A method of manufacturing a magnetic disk wherein at least a magnetic layer is formed on a surface of a glass substrate obtained according to one of the methods of manufacturing the glass substrate for a magnetic disk.

[0020]

(Seventh aspect)

A method of manufacturing a glass substrate for a magnetic disk, including a polishing step in which a polishing liquid containing abrasive grains is supplied between a glass substrate and a polishing pad for polishing a main surface of the glass substrate, and the glass substrate and the polishing pad are relatively moved to each other, thereby the main surface of the glass substrate is polished, wherein in the polishing step, a first polishing step is performed, in which when a glass substrate of which the main surface has a flat end is polished, the main surface of the glass substrate is polished such that a shape of

the end becomes a shape being protruded or descended compared with a central portion, and a second polishing step is performed, in which when a glass substrate of which the main surface has a flat end is polished, the main surface of the glass substrate is polished such that a shape of the end becomes a shape being descended or protruded compared with a central portion, thereby the end shape of the glass substrate is made into a substantially flat shape.

[0021]

(Eighth aspect)

A method of manufacturing a glass substrate for a magnetic disk, including a polishing step in which a polishing liquid containing abrasive grains is supplied between a glass substrate and a polishing pad for polishing a main surface of the glass substrate, and the glass substrate and the polishing pad are relatively moved to each other, thereby the main surface of the glass substrate is polished, and a chemical strengthening treatment step in which the glass substrate is contacted to a chemical strengthening treatment liquid, thereby part of ions contained in the glass substrate is substituted by ions in the chemical strengthening treatment liquid, and thereby a shape of an end of the main surface of the glass substrate becomes a shape being protruded compared with a central portion, wherein the polishing step includes a first polishing step, in which when a glass substrate of which the main surface has a flat end is polished, the main surface of the glass substrate is polished such that a shape of the end becomes a shape being protruded (or descended) compared with the central portion, and a second polishing step, in which when a glass substrate of which the main surface has a flat end is polished, the main surface of the glass substrate is polished such that a shape of the end becomes a shape being descended (or protruded) compared with the central portion, and the polishing step and the chemical strengthening treatment step are performed, thereby the end shape of the glass substrate is made into a substantially flat shape.

[0022]

Even in the seventh and eighth aspects, polishing is desirably performed in the second polishing step such that roughness (Ra) of the main surface of the glass substrate is 0.2 nm or less after the relevant second polishing step is performed.

[0023]

(Ninth aspect)

A method of manufacturing a magnetic disk wherein at least a magnetic layer is formed on a surface of the glass substrate obtained according to the method of manufacturing the glass substrate for a magnetic disk according to each of the seventh and eighth aspects.

[0024]

A polishing apparatus used in the invention includes a polishing apparatus of a glass substrate for a magnetic disk, which uses a plurality of sets, each set being configured by abrasive grains contained in a polishing liquid, and a polishing pad being relatively moved to the glass substrate while being supplied with the polishing liquid, thereby polishes a main surface of the glass substrate several times, wherein the plurality of sets include a first set that performs a preceding polishing step before a subsequent polishing step such that an end of the main surface has a shape being protruded (or descended) compared with a central portion, and a second set that performs the subsequent polishing step in which the protruded (or descended) shape is changed in a direction of cancelling the shape, thereby the end is made to be approximately flat.

[0025]

Moreover, the end of the main surface may be substantially flat as a result of the subsequent polishing step by using the second set. Alternatively, when the chemical strengthening treatment step is performed after the

subsequent polishing step, the end of the main surface may have a shape being descended compared with the central portion as a result of the relevant subsequent polishing step.

[0026]

A polishing pad of the second set may be high in hardness compared with a polishing pad of the first set, or a polishing pad of the second set may be low in hardness compared with a polishing pad of the first set.

Advantage of the Invention

[0027]

According to the invention, it is possible that change in end shape is cancelled between a plurality of treatment steps, so that a desired end shape is formed. In particular, it is possible that a protruded shape formed in a preceding polishing step is changed in a direction of cancelling the shape in a subsequent polishing step, so that an end of a glass substrate for a magnetic disk is made to be approximately flat.

[0028]

According to the invention, an end shape obtained in the subsequent polishing step can be made to be a substantially flat shape, or the end shape can be left as it is a descended shape. Such a descended shape is previously left in order to cancel a protruded shape formed in a chemical strengthening treatment step to be additionally performed after the subsequent polishing step, and the end of the glass substrate can be finally made to be substantially flat through the chemical strengthening treatment step.

Brief Description of the Drawings

[0029]

Fig. 1 is a diagram for illustrating a double-side polishing apparatus as

an embodiment of a polishing apparatus of a glass substrate for a magnetic disk according to the invention.

Fig. 2 is an enlarged section diagram for illustrating a configuration of a polishing pad used in the invention.

Fig. 3 is a schematic diagram for illustrating a method of manufacturing the glass substrate for a magnetic disk according to a first example of the invention using the polishing apparatus shown in Fig. 1.

Fig. 4 is sectional diagrams of a disk-like glass substrate taken along a plane perpendicular to a main surface through a center of the glass substrate.

Fig. 5 shows (a) a polishing condition in the first example of the invention, and (b) a polishing condition in a comparative example to be compared with the first example.

Fig. 6 is a schematic diagram for illustrating a method of manufacturing the glass substrate for a magnetic disk according to a second example of the invention using the polishing apparatus shown in Fig. 1.

Fig. 7 shows (a) a polishing condition in the second example of the invention, and (b) a polishing condition in a comparative example to be compared with the second example.

Best mode for Carrying Out the Invention

[0030]

First, meaning of terms "protrusion" (hereinafter, called "ski-jump"), "descending" (hereinafter, called "roll-off"), and "flatness", each expressing an end shape in the application, is described using Fig. 4. The "ski-jump" expresses a shape of an end of a main surface of a glass substrate, the shape being protruded (risen) compared with a central portion. On the other hand, "roll-off" expresses a shape of the end of the main surface of the glass substrate, the shape being descended (lowered) compared with the central portion. The

"flatness" expresses a shape (shape in a direction perpendicular to a main surface) of the end of the main surface of the glass substrate, the shape being approximately the same as a shape of the central portion. These are described in detail below.

[0031]

Fig. 4 shows sectional diagrams of a glass substrate 1 taken along a plane perpendicular to a main surface 1a through a center of the glass substrate 1, wherein Fig. 4(a) shows ski-jump, and Fig. 4(b) shows roll-off. In a recording area M on an outline of the flat, main surface 1a in Fig. 4(a) or 4(b), two reference points R1 and R2 are set in order from a point closer to the center. Moreover, a boundary line R3 (outer circumferential end position of a glide area G) perpendicular to the main surface 1a is set, which has a margin in a certain distance in a further outer circumferential direction from an outer circumferential end of the recording area M, and an intersection between the boundary line R3 and an outline of the glass substrate 1 is assumed as a roll-off point R. Next, a straight line R4 connecting between the points R1 and R2 is drawn. Then, in Fig. 4, it is assumed that the straight line R4 is a reference (having a value of zero), and an upward direction is a positive direction, and a downward direction is a negative direction. In this case, a point having the largest value in an area from the point R2 to the point R, namely, a point S on the outline of the glass substrate 1 in a position, which is maximally deviated in a positive direction from the straight line R4, is assumed as a ski-jump point. A value S5 of the ski-jump point S corresponds to a ski-jump value (height in a positive direction from the straight line R4). A value of the roll-off point R corresponds to a roll-off value R5 (height in a negative direction from the straight line R4).

[0032]

To describe in more detail, the points R1, R2 and R3 are set in a radial direction from the center of the glass substrate 1. Among these points, the

points R1 and R2 are set in the central portion of the glass substrate 1 (a position near the center in the radial direction of the glass substrate 1). Then, when the straight line R4 passing through the points R1 and R2 is drawn, deviations between the relevant straight line R4 and the surface of the glass substrate 1 (deviation in a direction perpendicular to the substrate surface) are measured between the points R2 and R3. Among the deviations, a point having a maximum deviation in a positive direction (rising direction) is the ski-jump point (point S), and a magnitude of such a deviation is assumed as the ski-jump value, and on the other hand, a point having a maximum deviation in a negative direction (lowering direction) is the roll-off point (point R), and a magnitude of such a deviation is assumed as the roll-off value.

[0033]

In Fig. 4(a), the ski-jump value S5 is positive, and the roll-off value R5 is negative. In Fig. 4(b), the ski-jump value S5 is zero, and the roll-off value R5 is negative. In the application, a shape in which the ski-jump value S5 is positive as in Fig. 4(a) is called ski-jump (a shape in which the end of the main surface 1a is protruded compared with the central portion), and a shape in which the ski-jump value is zero, and the roll-off value R5 is negative as in Fig. 4(b) is called roll-off (a shape in which the end of the main surface 1a is descended compared with the central portion). It is defined in the application that as an absolute value of the ski-jump value or the roll-off value is reduced, the end shape more approximates a flat shape, and when both of the ski-jump value and the roll-off value are zero, the end shape is a flat shape.

[0034]

The points R1 and R2, and the boundary line R3 are appropriately selected depending on size of the glass substrate 1. For example, when the glass substrate 1 has an outer diameter of 2.5 inches (outer diameter of 65 mm), the boundary line R3 is defined in a position 1 mm inside of the end face of the

glass substrate 1. Moreover, when the glass substrate 1 has an outer diameter of 2.5 inches, for example, respective distances from the center of the substrate can be defined as follows: a distance to the point R1 is 23 mm, a distance to the point R2 is 27 mm, a distance to the boundary line R3 is 31.5 mm, and a distance to the end face is 32.5 mm. In other words, with respect to the center of the glass substrate 1, a position in 71% of a distance to the outer diameter (end face) of the substrate can be set as the point R1, a position in 83% of the distance can be set as the point R2, and a position in 97% of the distance can be set as the point R3.

[0035]

When the absolute value of the ski-jump value or the roll-off value is excessively large, since the end shape is bad, flying stability of a magnetic head becomes bad, and rotational stability of a magnetic disk becomes bad, and head crush may occur in a worst case, disabling mounting of the magnetic disk on the magnetic disk drive, which is not preferable. The ski-jump value and the roll-off value are preferably within a range of $\pm 0.10 \mu\text{m}$ respectively, and more preferably within a range of $\pm 0.05 \mu\text{m}$.

[0036]

Which shape is formed between the ski-jump and the roll-off is determined based on various factors. For example, it is determined based on diameter of abrasive grains contained in a polishing liquid, hardness of a polishing pad, a polishing condition and the like.

[0037]

When flying height of the magnetic head is reduced, the end shape of the main surface of the glass substrate is obviously importantly concerned, in addition, roughness of the main surface as a whole and roughness of the end shape are importantly concerned. Since the magnetic head fries and runs from an inner circumferential end of the main surface to an outer circumferential end

thereof, roughness in each position, particularly roughness in the end of the main surface of the glass substrate, which rotates at higher speed, is importantly concerned.

[0038]

Specifically, when surface roughness is measured by AFM (Atomic Force Microscope), the main surface of the glass substrate preferably has a surface roughness of 0.2 nm or less. In this case, $R_{\max}$ is preferably 2 nm or less.

[0039]

Furthermore, when surface profiles in a band where a profile wavelength is 16 μm to 1.9 μm are extracted among surface profiles in a rectangular area of 3.8 square millimeters with a point as a center, the point being situated on the main surface at a distance of 2.5 mm from the outer circumferential end of a disk toward the center of the disk, and mean square roughness R_q (RMS) of the surface profiles is assumed as a small wave R_q , the small wave R_q is preferably 0.5 nm or less.

[0040]

[First Embodiment]

Next, first embodiment of each of a method of manufacturing a glass substrate for a magnetic disk, a method of manufacturing a magnetic disk, and a polishing apparatus of the glass substrate for a magnetic disk is described in detail with reference to accompanying drawings.

[0041]

[Polishing Apparatus of Glass Substrate for Magnetic Disk]

Fig. 1 shows a diagram illustrating a double-side polishing apparatus as a first embodiment of a polishing apparatus of a glass substrate for a magnetic disk according to the invention. A double-side polishing apparatus 3 uses a polishing pad 10, and performs polishing by relatively moving a glass substrate 1

and the polishing pad 10 to each other.

[0042]

Fig. 1(a) shows an explanatory diagram of a drive mechanism section of the double-side polishing apparatus, and Fig. 1(b) shows a sectional diagram of a major part of the double-side polishing apparatus having top and bottom boards. As shown in Fig. 1(a), the double-side polishing apparatus 3 includes a polishing carrier mounting section having an internal gear 34 and a sun gear 35, each gear being rotationally driven at a predetermined rotation ratio, and a top board 31 and a bottom board 32 with the polishing carrier mounting section between them, the boards being driven reversely rotationally to each other. A surface opposed to the glass substrate 1 of each of the top and bottom boards 31 and 32 is attached with a polishing pad 10 described later. Each of a plurality of polishing carriers 33 mounted so as to be meshed with the internal gear 34 and the sun gear 35 performs a planetary gear motion so as to revolve around the sun gear 35 while turning round on its own axis.

[0043]

The plurality of polishing carriers 33 hold a plurality of glass substrates 1 respectively. The top board 31 is movable in a vertical direction, and as shown in Fig. 1(b), presses the polishing pad 10 to main surfaces at both sides of each glass substrate 1. Then, while supplying a slurry containing abrasive grains, each polishing carrier 33 performs the planetary gear motion, and the top board 31 and the bottom board 32 rotate reversely to each other, thereby each glass substrate 1 and the polishing pad 10 are moved relatively to each other, so that the main surfaces at both sides of each glass substrate 1 are polished.

[0044]

The double-side polishing apparatus 3 configured as above can be used for polishing of the main surface of the glass substrate 1, the polishing being performed multiple times gradually in a manufacturing process of a glass

substrate by using a plurality of sets, each set including abrasive grains contained in a polishing liquid, and a polishing pad 10 being relatively moved with respect to the glass substrate 1 while being supplied with the polishing liquid. In an example described later, two polishing steps including a preliminary polishing (primary polishing) step and a mirror polishing (secondary polishing) step are carried out as a step of polishing the main surface of the glass substrate 1. Between the polishing steps, a configuration of the double-side polishing apparatus 3 is approximately the same, but abrasive grains contained in a polishing liquid (slurry) to be used and a composition of the polishing pad 10 are different. As a general tendency, as a step is a later step, diameter of abrasive grains is decreased, and hardness of the polishing pad 10 is decreased.

[0045]

However, when a substrate having low roughness compared with a prior art is obtained in a roughening step performed before the preliminary polishing step, a soft pad compared with a prior art may be used as a pad for the primary polishing (preliminary polishing). Therefore, a purpose of the primary polishing is sometimes sufficiently achieved even in polishing having small removal depth compared with a prior art. However, when the soft pad compared with a prior art is used in the primary polishing, protrusion (ski-jump) in a substrate end is sometimes more significantly formed. In such a case, the ski-jump formed in the primary polishing may not be sufficiently cancelled in the secondary polishing, consequently the substrate end may be remained in the shape of the ski-jump. Thus, as a method of solving that, in the embodiment, a polishing condition is changed in the secondary polishing as a latter step, for example, diameter of abrasive grains, or material or hardness of the polishing pad is changed, thereby ski-jump formed in the primary polishing is changed in a direction of cancelling the ski-jump in the secondary polishing, so that the end shape of the substrate is

approximated to a flat shape.

[0046]

Fig. 2 shows an enlarged section diagram for explaining a configuration of the polishing pad used in the invention. As shown in Fig. 2, for the polishing pad 10, a foamed body made of synthetic resin such as polyurethane or polyester is used. Particularly, formed polyurethane is preferable in the present condition. According to Fig. 2, the polishing pad 10 includes a base layer 13 including nonwoven fabric or the like, and a nap layer 14 stacked on a surface of the base layer 13. In such a nap layer 14, a plurality of bubbles are formed in a drop shape in a thickness direction of the nap layer 14. In the embodiments, the bubbles are assumed as nap holes 15. Hardness of such a foamed body can be adjusted by the amount of bubbles (nap holes 15) to be mixed into the body.

[0047]

[Method of manufacturing glass substrate for magnetic disk]

Fig. 3 shows a schematic diagram showing an embodiment of a method of manufacturing a glass substrate for a magnetic disk according to the invention by using the polishing apparatus shown in Fig. 1. The method includes a plurality of polishing steps as shown in Figs. 3(a) and 3(b). In the polishing steps, while a polishing liquid containing abrasive grains 40 or 50 is supplied, the glass substrate 1 and the polishing pad 10 or 20 are relatively moved to each other, so that a main surface of the glass substrate 1 is polished. Fig. 3(a) shows a preceding polishing step in which polishing is performed such that an end of the main surface has a shape being protruded (ski-jump) compared with a central portion of the main surface, and the step corresponds to a preliminary polishing step in an example described later. Fig. 3(b) shows a subsequent polishing step in which the protruded shape (ski-jump) is changed in a direction of cancelling the shape so that the end is approximated to a flat shape, which

corresponds to a mirror polishing step in the example described later. The preceding polishing step is achieved by a set configured by the abrasive grains 40 and the polishing pad 10, and the subsequent polishing step is achieved by a set configured by the abrasive grains 50 and the polishing pad 20.

[0048]

The "central portion" means an area including the center in a radial direction in an information recording area into which information is written when a magnetic disk is manufactured using the glass substrate for a magnetic disk, and corresponds to at least a part of the glide area G as shown in Fig. 4.

[0049]

The embodiment may further include a grasp step before the preceding polishing step of Fig. 3(a), in which the ski-jump shape as a shape of the end being protruded compared with the central portion, the shape being to be formed in the relevant preceding polishing step, is beforehand grasped in order to determine hardness of the polishing pad 20 and diameter of abrasive grains 50 used in the subsequent polishing step of Fig. 3(b). In the grasp step, for example, an end shape of the glass substrate is previously measured after a preceding polishing step, and a treatment condition in a subsequent polishing step can be determined based on the end shape.

[0050]

By providing such a grasp step, the polishing pad 20 used in the subsequent polishing step of Fig. 3(b) may be increased in hardness compared with the polishing pad 10 used in the preceding polishing step of Fig. 3(a). Hardness of the polishing pad 10 or 20 may be adjusted by the amount of bubbles to be mixed into each of the pads as above. Moreover, by providing the grasp step, abrasive grains used in the subsequent polishing step of Fig. 3(b) may be decreased in diameter compared with abrasive grains used in the preceding polishing step of Fig. 3(a). That is, the invention includes the grasp

step of beforehand grasping the end shape of the glass substrate obtained in the preceding polishing step, and the determination step of determining hardness of the polishing pad and diameter of the abrasive grains used in the subsequent polishing step.

[0051]

In the subsequent polishing step of Fig. 3(b), hardness of the polishing pad is increased, and/or diameter of abrasive grains is reduced as described above. In the step, if a glass substrate having a flat end is polished, polishing is performed such that the end has a shape being descended compared with the central portion (roll-off) as a glass substrate 100.

[0052]

Such polishing is applied to the glass substrate 1 of which the end already has the ski-jump shape, as a result, the end of the main surface can be substantially made to be flat as in Fig. 3(c). Alternatively, as a result of the subsequent polishing step of Fig. 3(b), the end of the main surface may be in a shape being descended compared with the central portion (roll-off). This is a polishing method where the end is allowed to have a roll-off shape in the subsequent polishing step based on expectation of change in end shape (ski-jump) which will occur in a chemical strengthening treatment step to be additionally performed after the subsequent polishing step. While it was described that the end was allowed to have the roll-off shape, it means that the end is allowed to have a roll-off shape as a shape being approximated to a flat shape compared with the ski-jump shape formed in the preliminary polishing step.

[0053]

Here, the preceding polishing step (primary polishing step or preliminary polishing step) and the subsequent polishing step (secondary polishing step or mirror polishing step) are described respectively.

[0054]

In the preceding polishing step according to the embodiment, an end shape of a glass substrate is formed such that the end shape of the glass substrate is a flat shape after the subsequent polishing step as described later. Specifically, in the preceding polishing step, when a glass substrate having a flat end of a main surface is polished, the main surface of the glass substrate is polished such that the end has a shape being protruded compared with a central portion.

[0055]

In the subsequent polishing step according to the embodiment, the end shape of the glass substrate is made into a flat shape. Specifically, in the subsequent polishing step, when a glass substrate having a flat end of a main surface is polished, the main surface of the glass substrate is polished such that the end has a shape being descended compared with a central portion.

[0056]

Moreover, in the subsequent polishing step, a surface of the glass substrate is polished into a mirror surface. Colloidal silica particles are preferably used for abrasive grains used in the subsequent polishing step. The content of colloidal silica particles in a polishing liquid is preferably 5 wt% to 40 wt%.

[0057]

Grain diameter of the colloidal silica particles is preferably 80 nm or less, and more preferably 50 nm or less. This is because if such fine abrasive grains are used, a smooth mirror surface, which is preferable for the glass substrate for a magnetic disk, can be obtained. A lower limit value of the grain diameter is preferably determined in consideration of polishing processing speed in the subsequent polishing step, and for example, the lower limit value can be determined to be 20 nm or more.

[0058]

In the subsequent polishing step, regarding surface roughness of the glass substrate 10, for example, polishing is performed such that arithmetic mean roughness (Ra) is 0.2 nm or less, and maximum peak height (Rp) is 2 nm or less. Here, the maximum peak height (Rp) means a height obtained as follows: a surface profile of a predetermined region in a surface of a glass substrate is measured, then a mean plane of the surface profile is obtained, and then assuming that the mean plane is as a reference, height of the highest point from the average surface is obtained, which corresponds to the relevant height. These values are measured using AFM (Atomic Force Microscope).

[0059]

[Method of manufacturing magnetic disk]

When at least a magnetic layer is formed on a surface of a glass substrate obtained according to the method of manufacturing the glass substrate for a magnetic disk so that a magnetic disk is manufactured, a magnetic disk is obtained, which has a desired end shape such as a magnetic disk having a substantially flat end.

[0060]

[Method of manufacturing glass substrate for magnetic disk]

When the invention is further generalized, an embodiment may be considered, which includes a first treatment step performed to the glass substrate 1, and a second treatment step in which the glass substrate 1 is changed in a direction of cancelling change in end shape of the glass substrate 1 appeared in the first treatment step in order to form a desired end shape. The first and second treatment steps, in which the end shape of the glass substrate 1 is changed in a direction of being cancelled by each other, are not limited to a plurality of polishing steps. That is, any embodiment can be considered, as long as it is corresponding to the technical idea that change in end shape in a

preceding step is changed in a direction of cancelling the change in a subsequent step.

[0061]

For example, the followings are listed:

(A) first treatment step; LAP (grinding), and second treatment step; polishing,

(B) first treatment step; chemical strengthening, and second treatment step; polishing, and

(C) first treatment step; preliminary polishing (primary polishing), and second treatment step; mirror polishing (secondary polishing).

The embodiment described using Figs. 1 to 3 corresponds to an example of the (C).

[0062]

In this way, since the end shape is changed in the treatment step such as polishing or chemical strengthening, before the first treatment step, change in end shape to be appeared in the step is grasped beforehand so that a treatment condition of the second treatment step may be determined. To beforehand grasp the change in end shape of the glass substrate, for example, it is enough that an end shape of the glass substrate is previously measured after a first treatment step.

[0063]

It is appreciated that the number of processing steps is not limited to two. For example, various patterns may be considered, including (D) steps of primary polishing, secondary polishing, and chemical strengthening, (E) steps of primary polishing, secondary polishing, chemical strengthening, and polishing, and (F) steps of the chemical strengthening, primary polishing, and secondary polishing. In any of patterns, it is only necessary that the end shape of the glass substrate becomes a desired shape after each process.

[0064]

When chemical strengthening is not performed, the end shape can be made flat in a last polishing step. However, when the chemical strengthening is performed after secondary polishing, and polishing is not performed thereafter as in the example (D), it is enough that a level of protrusion of the end shape formed in the chemical strengthening is grasped beforehand, and an end shape after secondary polishing is made to be the roll-off shape so that the end shape after the chemical strengthening becomes a flat shape. On the other hand, in a case that polishing is additionally performed after chemical strengthening (a case that roughness and an end shape are desirably improved while a strengthening layer is left) as in the examples (E) and (F), an end shape to be obtained by a chemical strengthening condition is grasped beforehand, and sufficient polishing to change the end shape in a direction of cancelling the end shape is performed for polishing with small removal depth to the utmost. Thus, the end shape and roughness can be improved while leaving the strengthening layer (while keeping sufficient strength). By performing such polishing, the end shape is made into a substantially flat shape.

[0065]

The generalized method of manufacturing the glass substrate for a magnetic disk may be also applied to a second embodiment described later.

[0066]

[First example]

In a first example, a glass substrate for a magnetic disk and a perpendicular magnetic recording disk were manufactured through the following steps of (1) to (11).

[0067]

(1) Shape machining step

First, a multicomponent glass substrate including amorphous glass was

prepared. A type of the glass was aluminosilicate glass, and a chemical composition of the glass was specified as SiO_2 of 63.5 wt%, Al_2O_3 of 14.2 wt%, Na_2O of 10.4 wt%, Li_2O of 5.4 wt%, ZrO_2 of 6.0 wt%, Sb_2O_3 of 0.4 wt%, and As_2O_3 of 0.1 wt%.

[0068]

The glass substrate was molded by a direct press method and thus formed into a disk-like glass substrate. Then, a hole was opened in a central portion of the glass substrate using a grindstone, so that a disk-like glass substrate 1 having a circular hole in the center was formed. Furthermore, an outer circumferential end face and an inner circumferential end face were chamfered.

[0069]

(2) End face polishing step

Next, while rotating the glass substrate 1, the glass substrate 1 was polished by brush polishing such that surface roughness of each of the (inner and outer circumferential) end faces of the glass substrate 1 was about $1.0\text{ }\mu\text{m}$ in the maximum height (R_{max}), and about $0.3\text{ }\mu\text{m}$ in the arithmetic mean roughness (R_a).

[0070]

(3) Grinding step

Next, while using grinding particles having a grain size of #1000, a glass substrate surface was ground such that a main surface had flatness of $3\text{ }\mu\text{m}$, R_{max} of about $2\text{ }\mu\text{m}$, and R_a of about $0.2\text{ }\mu\text{m}$. Here, the flatness means a distance (height difference) in a vertical direction (direction perpendicular to a surface) between the highest portion and the lowest portion of the substrate surface, which was measured by a flatness measurement apparatus. R_{max} and R_a were measured by an atomic force microscope (AFM) (Nanoscope manufactured by Digital Instruments Inc.).

[0071]

(4) Preliminary polishing step

In a preliminary polishing step, the glass substrate, which was ground in the grinding step (3) and then roughened, is first polished using a polishing pad. The preliminary polishing step was carried out using a polishing apparatus 3 that was able to polish both of main surfaces of each of 100 to 200 glass substrates at a time. For the polishing pad, a polyurethane series soft polisher was used. As the polishing pad, a polishing pad, in which a zirconium oxide and a cerium oxide were previously contained, was used.

[0072]

Fig. 5(a) shows a table showing a polishing condition in the example 1. A polishing liquid in the preliminary polishing (primary polishing) step was prepared by mixing cerium oxide abrasive grains 40 having a mean grain diameter of 1.2 μm into water. Diameter of the abrasive grains 40 is preferably within a range of 1.0 to 1.4 μm . Abrasive grains having a grain diameter of more than 4 μm were removed beforehand. The polishing liquid was measured, as a result, a maximum value of diameter of the abrasive grains contained in the polishing liquid was 3.5 μm , an average value of the diameter was 1.2 μm , and a D50 value thereof was 1.1 μm . In addition, a load applied to the glass substrate 1 was 80 to 100 g/cm^2 , and thickness of a surface portion to be removed from the glass substrate 1 was 20 to 40 μm .

[0073]

The “end shape” in the table of Fig. 5 shows an end shape in the case that only the relevant polishing step is singly performed. Specifically, it shows an end shape formed in the case that the relevant polishing step is performed using a glass substrate having a flat end. The “results” in the table of Fig. 5 show end shapes of the glass substrate after a series of the primary and secondary polishing steps are finished respectively.

[0074]

After the (4) preliminary polishing step was performed, an end shape was observed, as a result, it was known that the end shape was the ski-jump shape as shown in Fig. 3(a).

[0075]

(5) Mirror polishing step

In the mirror polishing step, the glass substrate subjected to the preliminary polishing is further polished until the main surface of the glass substrate becomes a mirror surface. The mirror polishing (secondary polishing) step was carried out using the polishing apparatus 3 that can polish both of main surfaces of each of 100 to 200 glass substrates at a time. For the polishing pad, a polyurethane series soft polisher was used. A polishing liquid in the mirror polishing step was prepared by adding colloidal silica particles having a grain diameter of 40 nm into ultrapure water. The grain diameter of the colloidal silica particles is desirably within a range of 20 to 60 nm. After the (5) mirror polishing step was performed, an end shape was observed, as a result, it was known that the end shape was a substantially flat shape as shown in Fig. 3(c).

[0076]

Using a glass substrate that has a flat end shape immediately before the (5) mirror polishing step, the (5) mirror polishing step was performed, as a result, the end shape became the roll-off shape as in the glass substrate 100 shown in Fig. 3(b).

[0077]

That is, in the invention, polishing is performed in the preliminary polishing step such that an end shape becomes the ski-jump shape, and polishing is performed in the subsequent mirror polishing step such that an end shape being initially a flat shape is made into the roll-off shape, so that an end shape of the glass substrate to be finally obtained is controlled to be a desired

flat shape.

[0078]

(6) Cleaning step after mirror polishing treatment

Next, the glass substrate 1 was dipped into a NaOH aqueous solution in a concentration of 3 to 5 wt% for alkali cleaning. The cleaning was performed with an ultrasonic wave being applied. Furthermore, the glass substrate was sequentially dipped in respective cleaning tanks of a neutral detergent, pure water, pure water, isopropyl-alcohol, and isopropyl-alcohol (steam drying), and thus washed. A surface of the glass substrate 1 after cleaning was observed by AFM (Nanoscope manufactured by Digital Instruments Inc.), as a result, adhesion of the colloidal silica abrasive grains was not confirmed. Moreover, foreign substances such as stainless steel or iron were not found.

[0079]

(7) Chemical strengthening treatment step

Next, the cleaned glass substrate 1 being preheated to 300°C was dipped for about 3 hours in a chemical strengthening salt including potassium nitrate (60%) and sodium nitrate (40%), which were mixed to each other and heated to 375°C, so that the substrate was subjected to chemical strengthening treatment. By performing the treatment, lithium ions and sodium ions in a surface of the glass substrate 1 are substituted by sodium ions and potassium ions in the chemical strengthening salt (ion exchange) respectively, so that the glass substrate 1 is chemically strengthened. Thickness of a compressive stress layer formed in the surface of the glass substrate 1 was about 100 to 200 μm . After performing the chemical strengthening, the glass substrate 1 was dipped in a water tank at 20°C to be rapidly cooled, and kept for about 10 min therein.

[0080]

As a result of the chemical strengthening treatment step, the end of the

glass substrate 1 sometimes expands due to compressive stress generating on the surface of the substrate and thus rises, resulting in formation of ski-jump. In such a case, when the preceding mirror polishing step is finished, a slight roll-off shape may be left on the end instead of making the end to be completely flat. That is, the end shape after the secondary polishing step (mirror polishing step) and/or the end shape after the primary polishing step (preliminary polishing step) may be adjusted such that a flat end shape is given after the chemical strengthening treatment step is performed.

[0081]

(8) Cleaning step after chemical strengthening

Next, the rapidly-cooled glass substrate 1 was dipped in sulfuric acid being heated to about 40°C, then the glass substrate was cleaned while being applied with an ultrasonic wave, and consequently manufacturing of a glass substrate for a magnetic disk was completed.

[0082]

(9) Inspection step of glass substrate for magnetic disk

Next, inspection was made on the glass substrate for a magnetic disk. Surface roughness of the glass substrate for a magnetic disk was measured by AFM (Atomic Force Microscope), as a result, the maximum peak height (R_p) was 1.8 nm, and the arithmetic mean roughness (R_a) was 0.25 nm. Moreover, the surface was a clean mirror surface, and a foreign substance that may disturb flying of a magnetic head, or a foreign substance that may cause a thermal asperity trouble was not found.

[0083]

(10) Magnetic disk manufacturing step

Next, for the glass substrate for a magnetic disk, an adhesion layer including a Cr alloy, a soft magnetic layer including a CoTaZr-based alloy, a base layer including Ru, a perpendicular magnetic recording layer including a

CoCrPt-based alloy, a protective layer including carbon hydride, and a lubricating layer including perfluoropolyether were sequentially deposited on a surface of the glass substrate, so that a perpendicular magnetic recording disk was manufactured.

[0084]

(11) Inspection step of magnetic disk

Next, inspection was made on the magnetic disk manufactured in the above way. First, a head crush test was performed, in which a head is allowed to fly and run on the magnetic disk by using an inspection head of which the flying height was 8 nm. As a result, the magnetic head did not contact to any foreign substance or the like, and consequently any crush trouble did not occur.

[0085]

Next, a magnetic head, of which the reproducing element section was a magnetoresistive effect element, the recording element section was a single pole element, and the flying height was 8 nm, was used for a recording/reproducing test by a perpendicular recording method, as a result, it was confirmed that information was normally recorded or reproduced. In this test, recording and reproducing were performed at 100 gigabits per square inch without detecting a thermal asperity signal in a reproducing signal.

[0086]

Next, a glide height test of the magnetic disk was performed. In the test, flying height of the inspection head is gradually reduced in order to confirm a flying height at which the inspection head begins to contact to the magnetic disk. As a result, the magnetic disk according to the example did not contact to the head over an area from an inner edge to an outer edge of the magnetic disk even in flying height of 4 nm. In an outer edge region of the magnetic disk, glide height was 3.7 nm.

[0087]

Fig. 5(b) shows a table showing a polishing condition in a comparative example to be compared with the example. Using a glass substrate obtained by the comparative example, a magnetic disk was produced, and subjected to a head crush test as in the above. As a result, the magnetic head contacted to a foreign substance or the like, and consequently a crush trouble occurred.

[0088]

When Fig. 5(a) is compared to Fig. 5(b), while grain diameter is approximately the same in either of the primary polishing and the secondary polishing, material of the polishing pad used in the primary polishing is different. When the polishing pad is compared between the examples, hardness of the polishing pad in Fig. 5(b) as the comparative example is 93 in C hardness in the primary polishing, and 84 in C hardness in the secondary polishing, that is, hardness of the polishing pad is low in the secondary polishing compared with in the primary polishing. On the other hand, hardness of the polishing pad in Fig. 5(a) as the example of the invention is 80 in C hardness in the primary polishing, and 84 in C hardness in the secondary polishing, that is, hardness of the polishing pad is high in the secondary polishing compared with the primary polishing.

[0089]

In addition to obtaining a desired end shape, in the light of processing speed (polishing speed), surface roughness of the substrate and the like, hardness of the polishing pad in Fig. 5(a) is desirably within a range of 78 to 82 in C hardness (ASKER C hardness) in the primary polishing, and is desirably within a range of 82 to 86 in C hardness in the secondary polishing. In other words, regarding hardness (ASKER C hardness) of the polishing pad used in the invention, the polishing pad used in the secondary polishing is preferably high in hardness compared with the polishing pad used in the primary polishing.

[0090]

In the first example of the invention, the shape of the glass substrate end, which became the ski-jump shape in the primary polishing, is changed in a direction of cancelling the change and into a roll-off shape having a roll-off value of $-0.046\text{ }\mu\text{m}$ in the secondary polishing. On the other hand, in the comparative example, the shape of the glass substrate end, which became the roll-off shape in the primary polishing, is not cancelled in the secondary polishing, in addition, the shape is a roll-off shape having a roll-off value of $0.173\text{ }\mu\text{m}$, of which the absolute value is increased. As obvious from the result, according to the example of the invention, changes in end shape appeared in the preceding and subsequent polishing steps are cancelled by each other, thereby the end shape can be more approximated to a flat shape. In other words, it is extremely difficult to finally manufacture a glass substrate for a magnetic disk, which has a flat end shape and a smooth main surface, only by adjusting each process, and it is important to continuously control the end shape through several processes. That is, the amount of change in end shape to be changed in the secondary polishing step is grasped beforehand, and an end shape in the primary polishing is adjusted such that the end shape becomes a flat shape after the secondary polishing is performed, thereby the glass substrate for a magnetic disk having a flat end shape can be manufactured.

[0091]

[Second embodiment]

Next, a second embodiment of a method of manufacturing a glass substrate for a magnetic disk, a method of manufacturing a magnetic disk, and a polishing apparatus of the glass substrate for a magnetic disk according to the invention are described in detail.

[0092]

[Polishing apparatus of glass substrate for magnetic disk]

For the polishing apparatus, the double-side polishing apparatus 3 as

described with reference to Fig. 1 in the first embodiment, and the polishing pad 10 as described with reference to Fig. 2 in the embodiment are used, therefore detailed description of them is omitted.

[0093]

Even in a second example described later, two polishing steps of a preliminary polishing (primary polishing) and a mirror polishing (secondary polishing) are carried out as a step of polishing a main surface of a glass substrate. Between the two steps, a configuration of the double-side polishing apparatus 3 is approximately the same, but abrasive grains contained in a polishing liquid (slurry) to be used, and a composition of the polishing pad 10 are different. As a general tendency, as a step is a later step, the abrasive grains are decreased in diameter, and the polishing pad 10 is decreased in hardness.

[0094]

However, depending on conditions such as hardness or material of the polishing pad, and diameter of the abrasive grains used in the primary polishing, descending (roll-off) of an end significantly occurs in some case. In such a case, the roll-off formed in the primary polishing may not be sufficiently canceled in the secondary polishing, consequently the end may be remained in the shape of the roll-off. Thus, as a method of solving that, in the second embodiment, a polishing condition is changed in the secondary polishing as a latter step, for example, diameter of the abrasive grains, or material or hardness of the polishing pad is changed, thereby roll-off formed in the primary polishing is changed in a direction of cancelling the roll-off in the secondary polishing, so that the end shape is approximated to a flat shape.

[0095]

[Method of manufacturing glass substrate for magnetic disk]

Fig. 6 shows schematic diagrams showing a second embodiment of a method of manufacturing the glass substrate for a magnetic disk according to

the invention by using the double-side polishing apparatus 3 shown in Fig. 1. The invention includes a plurality of polishing steps as shown in Figs. 6(a) and 6(b) as in the first embodiment. In the polishing steps, while a polishing liquid containing abrasive grains 40 or 50 is supplied, a glass substrate 1 and a polishing pad 10 or 20 are relatively moved to each other, so that a main surface of the glass substrate 1 is polished. Fig. 6(a) shows a preceding polishing step in which polishing is performed such that an end of the main surface has a shape being descended (roll-off) compared with a central portion of the main surface, and the step corresponds to a preliminary polishing step in a second example described later. Fig. 6(b) shows a subsequent polishing step in which the descended shape (roll-off) is changed in a direction of cancelling the change so that the end of the glass substrate 1 is approximated to a flat shape, which corresponds to a mirror polishing step in the second example described later. The preceding polishing step is achieved by a set configured by the abrasive grains 40 and the polishing pad 10, and the subsequent polishing step is achieved by a set configured by the abrasive grains 50 and the polishing pad 20.

[0096]

The second embodiment may further include a grasp step before a preceding polishing step of Fig. 6(a), in which the roll-off shape as a shape of the end being descended compared with the central portion, the shape being to be formed in the relevant preceding polishing step is beforehand grasped in order to determine hardness of the polishing pad 20 and diameter of abrasive grains 50 used in the subsequent polishing step of Fig. 6(b). In the grasp step, for example, an end shape of the glass substrate is previously measured after a preceding polishing step, and a treatment condition in a subsequent polishing step can be determined based on the end shape.

[0097]

By providing such a grasp step, the polishing pad 20 used in the

subsequent polishing step of Fig. 6(b) may be decreased in hardness compared with the polishing pad 10 used in the preceding polishing step of Fig. 6(a). Hardness of the polishing pad 10 or 20 may be adjusted by the amount of bubbles to be mixed into each of the pads as above. Moreover, by providing the grasp step, abrasive grains used in the subsequent polishing step of Fig. 6(b) may be decreased in diameter compared with abrasive grains used in the preceding polishing step of Fig. 6(a). That is, the second embodiment also includes the grasp step of beforehand grasping the end shape of the glass substrate obtained in the preceding polishing step, and the determination step of determining hardness of the polishing pad and diameter of the abrasive grains used in the subsequent polishing step.

[0098]

In the subsequent polishing step of Fig. 6(b), hardness of the polishing pad is decreased, and/or diameter of abrasive grains is increased as described above. In the step, if a glass substrate having a flat end is polished, polishing is performed such that the end has a shape being protruded compared with the central portion (ski-jump) as in a glass substrate 100.

[0099]

Such polishing is applied to the glass substrate 1 of which the end already has the shape of roll-off, as a result, the end of the main surface can be substantially made to be flat as in Fig. 6(c). Alternatively, as a result of the subsequent polishing step of Fig. 6(b), the end of the main surface may be in a shape being descended compared with the central portion (roll-off). This is a polishing method where the end is allowed to have the roll-off shape in the subsequent polishing step based on expectation of change in end shape (ski-jump) which will occur in a chemical strengthening treatment step to be additionally performed after the subsequent polishing step. While it was described that the end was allowed to have the roll-off shape, it means that the

end is allowed to have a roll-off shape as a shape being approximated to a flat shape compared with the roll-off shape formed in the preliminary polishing step.

[0100]

[Method of manufacturing magnetic disk]

As described in the first embodiment, when at least a magnetic layer is formed on a surface of a glass substrate obtained according to the method of manufacturing the glass substrate for a magnetic disk so that a magnetic disk is manufactured, a magnetic disk is obtained, which has a desired end shape such as a magnetic disk having a substantially flat end.

[0101]

[Second example]

Even in a second example, a glass substrate for a magnetic disk and a perpendicular magnetic recording disk were manufactured through the following steps of (1) to (11).

[0102]

(1) Shape machining step

First, a multicomponent glass substrate including amorphous glass was prepared. A type of the glass was aluminosilicate glass, and a chemical composition of the glass was specified as SiO_2 of 63.5 wt%, Al_2O_3 of 14.2 wt%, Na_2O of 10.4 wt%, Li_2O of 5.4 wt%, ZrO_2 of 6.0 wt%, Sb_2O_3 of 0.4 wt%, and As_2O_3 of 0.1 wt%.

[0103]

The glass substrate was molded by a direct press method and thus formed into a disk-like glass substrate. Then, a hole was opened in a central portion of the glass substrate using a grindstone, so that a disk-like glass substrate 1 having a circular hole in the center was formed. Furthermore, an outer circumferential end face and an inner circumferential end face were chamfered.

[0104]

(2) End face polishing step

Next, while rotating the glass substrate 1, the glass substrate 1 was polished by brush polishing such that surface roughness of each of the (inner and outer circumferential) end faces of the glass substrate 1 was about $1.0\ \mu\text{m}$ in the maximum height (R_{max}), and about $0.3\ \mu\text{m}$ in the arithmetic mean roughness (R_{a}).

[0105]

(3) Grinding step

Next, while using grinding particles having a grain size of #1000, a glass substrate surface was ground such that a main surface had flatness of $3\ \mu\text{m}$, R_{max} of about $2\ \mu\text{m}$, and R_{a} of about $0.2\ \mu\text{m}$. Here, the flatness means a distance (height difference) in a vertical direction (direction perpendicular to a surface) between the highest portion and the lowest portion of the substrate surface, which was measured by a flatness measurement apparatus. R_{max} and R_{a} were measured by an atomic force microscope (AFM) (Nanoscope manufactured by Digital Instruments Inc.).

[0106]

(4) Preliminary polishing step

In a preliminary polishing step, the glass substrate, which was ground in the grinding step (3) and then roughened, is first polished using a polishing pad. The preliminary polishing step was carried out using a polishing apparatus 3 that was able to polish both of main surfaces of each of 100 to 200 glass substrates at a time. For the polishing pad, a polyurethane series soft polisher was used. As the polishing pad, a polishing pad, in which a zirconium oxide and a cerium oxide were previously contained, was used.

[0107]

Fig. 7(a) shows a table showing a polishing condition in the second

example. A polishing liquid in the preliminary polishing (primary polishing) step was prepared by mixing cerium oxide abrasive grains 40 having a mean grain diameter of 1.2 μm into water. Diameter of the abrasive grains 40 is preferably within a range of 1.0 to 1.4 μm . A load applied to the glass substrate 1 was 80 to 100 g/cm^2 , and thickness of a surface portion to be removed from the glass substrate 1 was 20 to 40 μm .

[0108]

The "end shape" in the table of Fig. 7 shows an end shape in the case that only the relevant polishing step is singly performed. Specifically, it shows an end shape formed in the case that the relevant polishing step is performed using a glass substrate having a flat end. The "results" in the table of Fig. 7 show end shapes of the glass substrate after a series of the primary and secondary polishing steps are finished respectively.

[0109]

After the (4) preliminary polishing step was performed, an end shape was observed, as a result, it was known that the end shape was the roll-off shape as shown in Fig. 6(a).

[0110]

(5) Mirror polishing step

In a mirror polishing step, the glass substrate subjected to the preliminary polishing is further polished until the main surface of the glass substrate becomes a mirror surface. The mirror polishing (secondary polishing) step was carried out using the polishing apparatus 3 that can polish both of main surfaces of each of 100 to 200 glass substrates at a time. For the polishing pad, a polyurethane series soft polisher was used. A polishing liquid in the mirror polishing step was prepared by adding cerium oxide particles having a grain diameter of 0.5 μm into ultrapure water. A polishing material having a grain diameter of 0.3 μm or more is preferably used in order to form the ski-jump

shape in the mirror polishing (secondary polishing) step, and when finally obtained, mirror quality is considered, a polishing material having a grain diameter within a range of 0.3 to 0.6 μm is preferably used.

[0111]

After the (5) mirror polishing step was performed, an end shape was observed, as a result, it was known that the end shape was a substantially flat shape.

[0112]

Using a glass substrate which had a flat end shape immediately before the (5) mirror polishing step was performed, the (5) mirror polishing step was performed, as a result, the end shape became the ski-jump shape.

[0113]

That is, in the second embodiment, polishing is performed in the preliminary polishing step such that an end shape becomes the roll-off shape, and polishing is performed in the subsequent mirror polishing step such that an end shape being initially a flat shape is made into the ski-jump shape, so that an end shape of the glass substrate to be finally obtained is controlled to be a desired shape.

[0114]

(6) Cleaning step after mirror polishing treatment

Next, as in the first example, the glass substrate 1 was dipped into a NaOH aqueous solution in a concentration of 3 to 5 wt% for alkali cleaning. The cleaning was performed with an ultrasonic wave being applied. Furthermore, the glass substrate was sequentially dipped in respective cleaning tanks of a neutral detergent, pure water, pure water, isopropyl-alcohol, and isopropyl-alcohol (steam drying), and thus washed. A surface of the glass substrate 1 after cleaning was observed by AFM (Nanoscope manufactured by Digital Instruments Inc.), as a result, adhesion of the cerium oxide abrasive

grains was not confirmed. Moreover, foreign substances such as stainless steel or iron were not found.

[0115]

(7) Chemical strengthening treatment step

Next, as in the first example, the cleaned glass substrate 1 being preheated to 300°C was dipped for about 3 hours in a chemical strengthening salt including potassium nitrate (60%) and sodium nitrate (40%), which were mixed to each other and heated to 375°C, so that the substrate was subjected to chemical strengthening treatment. By performing the treatment, lithium ions and sodium ions in a surface of the glass substrate 1 are substituted by sodium ions and potassium ions in the chemical strengthening salt (ion exchange) respectively, so that the glass substrate 1 is chemically strengthened. Thickness of a compressive stress layer formed in the surface of the glass substrate 1 was about 100 to 200 μm . After performing the chemical strengthening, the glass substrate 1 was dipped in a water tank at 20°C to be rapidly cooled, and kept for about 10 min in the tank.

[0116]

As a result of the chemical strengthening treatment step, the surface of the glass substrate 1 sometimes expands and thus rises, resulting in formation of ski-jump. In such a case, when the preceding mirror polishing step is finished, a slight roll-off shape may be left on the surface instead of making the end to be completely flat.

[0117]

(8) Cleaning step after chemical strengthening

Next, as in the first example, the rapidly-cooled glass substrate 1 was dipped in sulfuric acid being heated to about 40°C, then the glass substrate was cleaned while being applied with an ultrasonic wave, and consequently manufacturing of a glass substrate for a magnetic disk was completed.

[0118]

(9) Inspection step of glass substrate for magnetic disk

Next, inspection was made on the glass substrate for a magnetic disk. The surface was in a state of a clean mirror, and a foreign substance that may disturb flying of a magnetic head, or a foreign substance that may cause a thermal asperity trouble was not found.

[0119]

(10) Magnetic disk manufacturing step

Next, as in the first example, using the glass substrate for a magnetic disk, an adhesive layer including a Cr alloy, a soft magnetic layer including a CoTaZr-based alloy, a base layer including Ru, a perpendicular magnetic recording layer including a CoCrPt-based alloy, a protective layer including carbon hydride, and a lubricating layer including perfluoropolyether were sequentially deposited on a surface of the glass substrate, so that a perpendicular magnetic recording disk was manufactured.

[0120]

(11) Inspection step of magnetic disk

Next, inspection was made on the magnetic disk manufactured in the above way. First, a head crush test was performed, in which a head is allowed to fly and run on the magnetic disk by using an inspection head of which the flying height was 8 nm. As a result, the magnetic head did not contact to any foreign substance or the like, and consequently any crush trouble did not occur.

[0121]

Next, a magnetic head, of which the reproducing element section was a magnetoresistive effect element, the recording element section was a single pole element, and the flying height was 8 nm, was used for a recording/reproducing test by a perpendicular recording method, as a result, it was confirmed that information was normally recorded or reproduced. In this

test, recording and reproducing were performed at 100 gigabits per square inch without detecting a thermal asperity signal in a reproducing signal.

[0122]

Next, a glide height test of the magnetic disk was performed. In the test, flying height of the inspection head is gradually reduced in order to confirm a flying height at which the inspection head begins to contact to the magnetic disk. As a result, the magnetic disk according to the example did not contact to the head over an area from an inner edge to an outer edge of the magnetic disk even in flying height of 4 nm. In an outer edge region of the magnetic disk, glide height was 3.7 nm.

[0123]

Using a glass substrate obtained by the comparative example according to a prior art which is different from a method where an end shape is changed in a direction of cancelling the shape as in the invention, a magnetic disk was produced, and subjected to a head crush test as in the above. As a result, the magnetic head contacted to a foreign substance or the like, and consequently a crush trouble occurred.

[0124]

Fig. 7(b) shows a table showing a polishing condition in a comparative example to be compared with the second example. Using a glass substrate obtained by the comparative example, a magnetic disk was produced, and subjected to a head crush test as in the above. As a result, the magnetic head contacted to a foreign substance or the like, and consequently a crush trouble occurred.

[0125]

When Fig. 7(a) is compared to Fig. 7(b), while grain diameter is the same in either of the primary polishing and the secondary polishing, material of the polishing pad used in the primary polishing is different. When the polishing

pad is compared between the examples, hardness of the polishing pad in Fig. 7(b) as the comparative example is 93 in C hardness in the primary polishing, and 84 in C hardness in the secondary polishing, that is, hardness of the polishing pad is low in the secondary polishing compared with in the primary polishing. On the other hand, hardness of the polishing pad in Fig. 7(a) as the second example of the invention is 90 in C hardness in the primary polishing, and 72 in C hardness in the secondary polishing, that is, hardness of the polishing pad is also low in the secondary polishing compared with the primary polishing, but values of hardness are different from those in Fig. 7(b).

[0126]

Hardness of the polishing pad in Fig. 7(a) is desirably within a range of 90 to 96 in C hardness (ASKER C hardness) in the primary polishing, and is desirably within a range of 70 to 86 in C hardness in the secondary polishing.

[0127]

In the second example of the invention, the shape of the glass substrate end, which became the roll-off shape in the primary polishing, is changed in a direction of cancelling the change and into a ski-jump shape having a ski-jump value of $0.034\ \mu\text{m}$ in the secondary polishing. On the other hand, in the comparative example, the shape of the glass substrate end, which became the roll-off shape in the primary polishing, is not cancelled in the secondary polishing, in addition, the shape is a roll-off shape having a roll-off value of $-0.173\ \mu\text{m}$, of which the absolute value is increased. As obvious from the result, according to the second example of the invention, changes in end shape appeared in the preceding and subsequent polishing steps are cancelled by each other, thereby the end shape can be more approximated to a flat shape.

Industrial Applicability

[0128]

The invention can be used for a method of manufacturing a glass substrate for a magnetic disk used as a recording medium of a computer and the like, and a method of manufacturing the magnetic disk.

CLAIMS

1. A method of manufacturing a glass substrate for a magnetic disk including a plurality of polishing steps, in which a polishing liquid containing abrasive grains is supplied between a glass substrate and a polishing pad for polishing a main surface of the glass substrate, and the glass substrate and the polishing pad are relatively moved to each other, thereby the main surface of the glass substrate is polished, wherein:

the plurality of polishing steps include:

a preceding polishing step for performing polishing by using a first set comprised of first abrasive grains and a first polishing pad; and

a subsequent polishing step for performing polishing by using a second set comprised of second abrasive grains and a second polishing pad; and wherein:

the first and/or second set are selected such that an end shape of the main surface of the glass substrate obtained by the preceding polishing step is changed in a direction of cancelling in the subsequent polishing step.

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

the method further comprises:

a grasp step of previously grasping the end shape obtained by the preceding polishing step; and

a determination step for determining hardness of the second polishing pad and diameter of the second abrasive grains based on the end shape grasped in the grasp step.

3. The method of manufacturing the glass substrate for a magnetic disk according to claim 1 or 2, wherein:

the end shape obtained by the preceding polishing step is a protruded shape compared with a central portion, and a polishing pad is used, as the second polishing pad, having high hardness compared with the first polishing pad.

4. The method of manufacturing the glass substrate for a magnetic disk according to claim 3, wherein:

the hardness of the first polishing pad is within a range of 78 to 82 in ASKER C hardness, and the hardness of the second polishing pad is within a range of 82 to 86 in ASKER C

hardness.

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

a cerium oxide is used as the first abrasive grains, and colloidal silica particles are used as the second abrasive grains.

6. The method of manufacturing the glass substrate for a magnetic disk according to claim 5, wherein:

diameter of the cerium oxide is within a range of 1.0 to 1.4 μm , and diameter of the colloidal silica particles is within a range of 20 to 60 nm.

7. The method of manufacturing the glass substrate for a magnetic disk according to claim 1 or 2, wherein:

the end shape obtained by the preceding polishing step is a descended shape compared with a central portion, and a polishing pad is used, as the second polishing pad, having low hardness compared with the first polishing pad.

8. The method of manufacturing the glass substrate for a magnetic disk according to claim 3, wherein:

the hardness of the first polishing pad is within a range of 90 to 96 in ASKER C hardness, and the hardness of the second polishing pad is within a range of 70 to 86 in ASKER C hardness.

9. The method of manufacturing the glass substrate for a magnetic disk according to claim 7 or 8, wherein:

a cerium oxide is used as the first and the second abrasive grains.

10. The method of manufacturing the glass substrate for a magnetic disk according to claim 9, wherein:

diameter of the cerium oxide as the first abrasive grains is within a range of 1.0 to 1.4 μm , and diameter of the cerium oxide as the second abrasive grains is within a range of 0.3 to 0.6 nm.

11. A method of manufacturing a glass substrate for a magnetic disk including a plurality of polishing steps, in which a polishing liquid containing abrasive grains is

supplied between a glass substrate and a polishing pad for polishing a main surface of the glass substrate, and the glass substrate and the polishing pad are relatively moved to each other, thereby the main surface of the glass substrate is polished, wherein:

the plurality of polishing steps include:

a preceding polishing step for performing polishing such that an end shape of the main surface of the glass substrate becomes a shape being protruded compared with a central portion of the main surface; and

a subsequent polishing step for performing polishing such that the end shape becomes a desired shape by changing the glass substrate in a direction of cancelling the end shape obtained by the preceding polishing step; and wherein:

a cerium oxide is used in the preceding polishing step as the abrasive grains, and colloidal silica particles are used in the subsequent polishing step as the abrasive grains.

12. A method of manufacturing a glass substrate for a magnetic disk including a plurality of polishing steps, in which a polishing liquid containing abrasive grains is supplied between a glass substrate and a polishing pad for polishing a main surface of the glass substrate, and the glass substrate and the polishing pad are relatively moved to each other, thereby the main surface of the glass substrate is polished, wherein:

the plurality of polishing steps include:

a preceding polishing step for performing polishing such that an end shape of the main surface of the glass substrate becomes a shape being protruded compared with a central portion of the main surface; and

a subsequent polishing step for performing polishing such that the end shape becomes a desired shape by changing the glass substrate in a direction of cancelling the end shape obtained by the preceding polishing step; and wherein:

the polishing pad used in the subsequent polishing step is high in hardness than the polishing pad used in the preceding polishing step.

13. The method of manufacturing the glass substrate for a magnetic disk according to any one of claim 1-12, wherein:

an end shape of the main surface of the glass substrate after the subsequent polishing step is a descended shape

compared with the central portion, and a chemical strengthening treatment step is performed after the subsequent polishing step, the chemical strengthening treatment step is that the glass substrate is contacted to a chemical strengthening treatment liquid, thereby part of ions contained in the glass substrate is substituted by ions in the chemical strengthening treatment liquid.

14. A method of manufacturing a glass substrate for a magnetic disk including:

a chemical strengthening treatment step in which the glass substrate is contacted to a chemical strengthening treatment liquid, thereby part of ions contained in the glass substrate is substituted by ions in the chemical strengthening treatment liquid; and

a polishing step in which a polishing liquid containing abrasive grains is supplied between the glass substrate and a polishing pad for polishing a main surface of the glass substrate, and the glass substrate and the polishing pad are relatively moved to each other, thereby the main surface of the glass substrate is polished; wherein the method further comprises:

previously grasping an end shape of the main surface of the glass substrate obtained by the chemical strengthening treatment step; and

determining a polishing condition of the polishing step such that the end shape becomes flat.

15. The method of manufacturing the glass substrate for a magnetic disk according to any one of claims 1-14, wherein:

roughness (Ra) of the main surface of the glass substrate for the magnetic disk is 0.2 nm or less.

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

a ski-jump value and a roll-off value of the glass substrate for the magnetic disk are within a range of $\pm 0.10 \mu\text{m}$, respectively, the ski-jump value being defined by a height of a ski-jump point which is maximally deviated in a positive direction from a straight line defined by the main surface, the roll-off value being defined by a height of a roll-off point which is deviated in a negative direction from the straight line defined by the main surface, the roll-off point

being defined by an intersection between an outline of the glass substrate and a boundary line set at the position, which has a margin in a certain distance in a further outer circumferential direction from an outer circumferential end of a recording media of the magnetic disk.

17. A method of manufacturing a magnetic disk, wherein:
at least a magnetic layer is formed on a surface of a glass substrate obtained according to the method of manufacturing the glass substrate for a magnetic disk according to any one of claims 1 to 16.