

DESCRIPTION

MAGNETIC DISK SUBSTRATE, MAGNETIC DISK AND HARD DISK DRIVE APPARATUS

Technical Field

[0001]

The present invention relates to a magnetic disk substrate that is mounted on a hard disk drive apparatus.

Background Art

[0002]

As a magnetic recording medium that is mounted on a hard disk drive apparatus (HDD apparatus), a magnetic disk is known. The magnetic disk is produced by depositing a NiP film on a metal substrate such as an aluminum-magnesium alloy substrate or by laminating a magnetic layer and a protective layer on a glass substrate or a ceramic substrate. Conventionally, an aluminum alloy substrate has been widely used as a magnetic disk substrate. However, with the recent reductions in size and thickness and the increase in recording density of the magnetic disk, a glass substrate has become to be used because of its excellent evenness in the surface and high strength as a thin film, compared to the aluminum alloy substrate.

[0003]

In a magnetic disk substrate, in particular, in a glass substrate, a chamfered surface is provided between a main surface and an end surface in order to prevent the substrate from being broken. Regarding the chamfered surface, for example, it is proposed to decrease the roughness of the chamfered surface for preventing corrosion or to form a surface having a

curvature (R surface) between the main surface and the chamfered surface for preventing occurrence of particles. For example, JP-A-2006-92722 (Patent Document 1) discloses a technology relating to the above.

[0004]

[Patent Document 1] JP-A-2006-92722

Disclosure of Invention

Problems to be Solved by the Invention

[0005]

Recently, the HDD apparatus has employed a load/unload system in which a magnetic head is withdrawn to the outside of the substrate when the disk is stopping, instead of a CSS (contact start and stop) system in which the magnetic head is in contact with the substrate surface when the disk is stopping. Furthermore, in the HDD apparatus, the rotation speed of the magnetic disk has become 7200 rpm or more, and it is predicted that the rotation speed will become 10000 rpm or more, in the future.

[0006]

Thus, when the system and the rotation speed of an HDD apparatus are considered, parameters such as sizes and roughnesses of the main surface, the chamfered surface, and the side surface are determined from the viewpoints of preventing head crashes and accurately performing data recording and data reproduction. In addition, parameters of the positions of boundary points between the main surface and the chamfered surface have desired accuracies. However, even if a substrate satisfying required various parameters is used, currently, head crashes occur at a certain rate and cannot be completely prevented.

[0007]

The present invention was made in the light of the above points, and an

object thereof is to provide a magnetic disk substrate and a magnetic disk that can prevent occurrence of head crashes in an HDD apparatus with a very high rate of success.

Means for Solving the Problems

[0008]

A magnetic disk according to the present invention has a substantially flat main surface, an end surface, and a chamfered surface between the main surface and the end surface and having a substantially circular shape.

Crossing points at which directions along the main surface and directions along the chamfered surface intersect are located at substantially the same distance from the center of the magnetic disk substrate in a planar view of the main surface over a whole circumference of the magnetic disk substrate.

[0009]

According to this configuration, variation in the positions of boundary points between the main surface and the chamfered surface can be reduced to a certain level or less by forming the chamfered surface such that the positions of the crossing points in the main surface are in the range described above.

As a result, a glass substrate that can prevent head crashes with a very high rate of success can be realized.

[0010]

In the magnetic disk substrate according to the present invention, it is preferable that projected points of the crossing points onto the chamfered surface in the planar view of the main surface are substantially the same position in a thickness direction of the magnetic disk substrate over the whole circumference of the magnetic disk substrate.

[0011]

A magnetic disk according to the present invention has a substantially flat

main surface, an end surface, and a chamfered surface between the main surface and the end surface and having a substantially circular shape. The circularity of a circle formed by crossing points in a planar view of the main surface is 0.5 mm or less where a first distance is a distance from a center of the magnetic disk substrate to the end surface and where the crossing points are each expressed by an intersection point of a first virtual line that connects points on the main surface at positions spaced from the center at 50% and 80% distances in the first distance and a second virtual line that connects points on the chamfered surface at positions spaced from the end surface at 0.15% and 0.30% distances in the first distance.

[0012]

According to this configuration, variation in the positions of boundary points between the main surface and the chamfered surface can be reduced to a certain level or less by forming the chamfered surface such that the positions of the crossing points in the main surface are in the range described above. As a result, a glass substrate that can prevent head crashes with a very high rate of success can be realized.

[0013]

In the magnetic disk substrate according to the present invention, it is preferable that second distances from the crossing points to the projected points of the crossing points onto the chamfered surface in the planar view of the main surface are each 15 μm or less.

[0014]

In the magnetic disk substrate according to the present invention, it is preferable that variation in the second distances is 5 μm or less over a whole circumference of the magnetic disk substrate.

[0015]

In the magnetic disk substrate according to the present invention, it is

preferable that the distance between a center of a circle formed by the crossing points in the planar view of the main surface and a center of the magnetic disk substrate is 1200 μm or less.

[0016]

In the magnetic disk substrate according to the present invention the magnetic disk substrate is preferably made of glass.

[0017]

A magnetic disk according to the present invention comprises the magnetic disk substrate mentioned above and a magnetic layer provided on the magnetic disk substrate.

[0018]

Preferably, the magnetic disk according to the present invention is mounted on a magnetic disk apparatus of a system in which a magnetic head is loaded on and unloaded from the main surface of the magnetic disk through an outer edge of the magnetic disk. Alternatively, the magnetic disk according to the present invention may be mounted to a magnetic disk apparatus of a CSS (contact start and stop) system.

[0019]

The magnetic disk according to the present invention is preferably mounted on a magnetic disk apparatus in which the magnetic disk is rotated at least at a rotation speed of 7200 rpm.

[0020]

In the magnetic disk according to the present invention, a touch-down height is preferably 4 nm or less.

[0021]

In the magnetic disk according to the present invention, a recording density is preferably 200 Gbit/inch² or more.

[0022]

A hard disk drive according to the present invention comprises the magnetic disk mentioned above, and a magnetic head for carrying out data recording and/or reproduction for the magnetic disk.

Advantages

[0023]

The magnetic disk substrate of the present invention includes a substantially flat main surface, an end surface, and a chamfered surface between the main surface and the end surface and has a substantially circular shape. The crossing points at which directions along the main surface and directions along the chamfered surface intersect are located at substantially the same distance from the center of the magnetic disk substrate in a planar view of the main surface over the whole circumference of the magnetic disk substrate, and thereby occurrence of head crashes in the HDD apparatus can be prevented with a very high rate of success.

Brief Description of Drawings

[0024]

Fig. 1 is a diagram partially showing a glass substrate serving as a magnetic disk substrate according to an embodiment of the present invention.

Fig. 2 includes a diagram (a) partially showing the glass substrate shown in Fig. 1, a magnified view (b) of the portion X in the (a), and a plan view (c) of a glass substrate 1.

Fig. 3 includes diagrams (a) and (b) for describing conditions near the ends of a glass substrate.

Fig. 4 is a schematic diagram showing a polishing apparatus used for producing a glass substrate serving as a magnetic disk substrate according to the embodiment of the present invention.

Fig. 5 is an exploded diagram schematically showing a structure of an HDD apparatus.

Fig. 6 includes diagrams showing variations in the positions of crossing points in main surfaces.

Fig. 7 includes diagrams showing variations in the positions of crossing point spaces in main surfaces.

Fig. 8 is characteristic curves showing relationships between variations in the positions of crossing points in main surfaces and head crashes.

Best Mode for Carrying Out the Invention

[0025]

The present inventors conducted an operation test using substrates satisfying management values that are required for positions of boundary points between main surfaces and chamfered surfaces and, from the results, focused on the occurrence of head crashes in some samples. Furthermore, the present inventors conducted an operation test in the same manner by using substrates that satisfy more strict management values of the parameters (managing under conditions more strict than required values). The results were that the occurrence rate of head crashes was relatively reduced, but head crashes still occurred. Accordingly, the present inventors have focused on, as a cause of the head crash, the variation in positions of boundary points between a main surface and a chamfered surface and have found that the head crashes can be prevented with a very high rate of success by controlling the variation in the positions of the boundary points to a certain level or less. Thus, the present invention was accomplished.

[0026]

That is, the gist of the present invention is to prevent the occurrence of head crashes in an HDD apparatus with a very high rate of success by that a

magnetic disk substrate includes a substantially flat main surface, an end surface, and a chamfered surface between the main surface and the end surface and has a substantially circular shape, wherein the crossing points at which directions along the main surface and directions along the chamfered surface intersect are located at substantially the same distance from the center of the magnetic disk substrate in a planar view of the main surface over the whole circumference of the magnetic disk substrate.

[0027]

An embodiment of the present invention will now be described in detail with reference to the accompanying drawings.

[0028]

In the embodiment, a case of a magnetic disk substrate made of glass will be described, but the present invention is not limited thereto, and the magnetic disk substrate may be made of a metal or ceramics.

[0029]

Fig. 1 is a diagram partially showing a glass substrate serving as a magnetic disk substrate according to the embodiment of the present invention. The glass substrate 1 shown in Fig. 1 has a substantially circular shape and has a hole 11 at the center for being loaded on a spindle motor of an HDD apparatus. In addition, the glass substrate 1 has a pair of main surfaces 12 opposing each other and an end surface (side wall surface) 13 at its outer circumferential edge. Furthermore, the glass substrate 1 has chamfered surfaces 14 between the main surfaces 12 and the end surface 13 over the whole circumference. The glass substrate 1 has an outside diameter D2 (distance from the center C of the substrate to the end surface 13), and the hole 11 has an inside diameter D1. Furthermore, the glass substrate 1 is fabricated so as to have substantially flat main surfaces.

[0030]

The glass substrate 1 may be produced by molding molten aluminosilicate glass into a disk shape by direct press or may be produced by cutting a glass sheet formed by a down-draw method or a float method with a grinding wheel into a disk-shaped glass substrate. The aluminosilicate glass is easy in its chemical strengthening treatment and is therefore preferred. As the aluminosilicate glass, glass for chemical strengthening may be used. In addition, instead of the aluminosilicate glass, another multi-component glass or crystallized glass may be used. The multi-component glass can be improved in the shock resistance by chemical strengthening treatment and is therefore preferred.

[0031]

Fig. 2(a) is a diagram partially showing the glass substrate shown in Fig. 1, Fig. 2(b) is a magnified view of the portion X in Fig. 2(a), and Fig. 2(c) is a plan view of a glass substrate 1. As shown in Fig. 2(b), the boundary region between the main surface 12 and the chamfered surface 14 does not actually have a clear boundary between the main surface 12 and the chamfered surface 14, and the main surface 12 gradually changes to the chamfered surface 14. In the present invention, the position of the boundary point (crossing point CP) between the main surface 12 and the chamfered surface 14 is the position at which a direction A along the main surface 12 and a direction B along the chamfered surface 14 intersect. Furthermore, the crossing point CP can be expressed by the intersection point of a virtual line (A) and a virtual line (B), where the distance (D2) is a distance from the center C of the glass substrate 1 to the end surface 13, the virtual line (A) connects points on the main surface 12 at positions spaced from the center C at distances corresponding to 50% and 80% of the distance (D2), and the virtual line (B) connects points on the chamfered surface 14 at positions spaced from the end surface 13 at distances corresponding to 0.15% and 0.30% of the distance (D2). Furthermore, the

points for defining the virtual lines are illustrative only and are not limited to the above-mentioned points in the outside diameter, as long as the points can substantially specify the positions of boundary points between the main surface 12 and the chamfered surface 14.

[0032]

As shown in Fig. 2(c), the crossing points CP specified as in above lie at substantially the same distance from the center C of the glass substrate 1 in a planar view of the main surface 12 over the whole circumference of the glass substrate 1. That is, in Fig. 2(c), the distances E from the center C of the glass substrate 1 to the crossing points CP are substantially the same over the whole circumference of the glass substrate 1. The "substantially the same" can be defined by the circularity of a circle formed by the crossing points CP in a planar view or the relationship between the center of a circle formed by the crossing points CP and the center C of the glass substrate 1. That is, the circularity of a circle (circle CP in Fig. 2(c)) formed by the crossing points CP in a planar view of the main surface 12 is preferably 0.5 mm or less. Alternatively, even if the center of a circle (circle CP in Fig. 2(c)) formed by the crossing points CP in a planar view of the main surface 12 and the center C of the glass substrate 1 deviate from each other, the distance between them is preferably 1200 μm or less.

[0033]

Here, the term "circularity" refers to a degree of deviation of a circular shape from a geometrically true circle. That is, the "circularity" is defined by a difference in radii of two concentric geometrically true circles when the circular shape is placed between the two concentric circles such that the distance between the concentric circles is the smallest. Specifically, the "circularity" is shown by the difference between the maximum diameter and the minimum diameter, as shown in Fig. 6 or 7.

[0034]

In addition, the projected points CP' of the crossing points CP onto the chamfered surface 14 in a planar view of the main surface 12 are preferably substantially the same position in the thickness direction of the glass substrate 1 over the whole circumference of the glass substrate 1. That is, in Fig. 2(b), it is preferable that the distances t from crossing points CP to the projected points of the crossing points CP onto the chamfered surface 14 in a planar view of the main surface 12 are substantially the same over the whole circumference of the glass substrate 1, in other words, that the variation in the distances t over the whole circumference of the glass substrate 1 is $5\text{ }\mu\text{m}$ or less (a variation of $5\text{ }\mu\text{m}$ or less). In this case, each distance t is preferably $15\text{ }\mu\text{m}$ or less.

[0035]

Thus, by forming the chamfered surface 14 such that the crossing points CP and the distances t are within the above-mentioned ranges, the variation in the positions of boundary points between the main surface 12 and the chamfered surface 14 can be suppressed to a certain level or less. As a result, a glass substrate that can prevent head crashes with a very high rate of success can be provided.

[0036]

The present applicant focused on so-called ski jump (convex shape) and roll off (concave shape) in the outer edge of a magnetic disk substrate and has proposed to control these shapes so as to satisfy certain conditions for preventing head crashes (Japanese Patent Application No. 2007-38926). That is, in the proposal, head crashes are prevented by regulating the heights or distances or the positions in the main surface 12 of the extreme portion 21 of the ski jump shown in Fig. 3(a) or the extreme portion 21 of the roll off shown in Fig. 3(b). The entire content is incorporated herein by reference. Therefore, head crashes can be further effectively prevented by specifying the crossing

points CP and the distances t as described above and also controlling the shapes of ski jump and roll off so that certain conditions are satisfied. In addition, head crashes can be more effectively prevented by controlling the distance F between the extreme portion 21 of the ski jump or the roll off shown in Fig. 3 and the crossing point CP within a certain range.

[0037]

In the embodiment, the conditions that are satisfied by the chamfered surface 14 of the outer edge of the glass substrate 1 are described, but in the present invention, the conditions can be similarly applied to the chamfered surface provided to the hole 11 of the glass substrate 1. In the case that the chamfered surface of the hole 11 satisfies the above-described conditions, the magnetic disk can be uniformly applied with a load when it is set in and clamped to an HDD apparatus. Therefore, it is further preferable that the chamfered surface 14 of the outer edge of the glass substrate 1 and the chamfered surface of the hole 11 both satisfy the above-described conditions.

[0038]

A method of producing the glass substrate will now be described.

[0039]

The method of producing the glass substrate includes (1) a shape processing step and a first lapping step, (2) an end shape forming step (a coring step for forming a hole and a chamfering step (chamfered surface forming step) for forming chamfered surfaces on ends (outer circumferential end and inner circumferential end), (3) an end surface polishing step (outer circumferential end and inner circumferential end), (4) a second lapping step, (5) a main surface polishing step (first and second polishing steps), (6) a chemical strengthening step, and (7) a texture treatment step. The order of the end polishing step and the second lapping step may be reversed. Furthermore, the texture treatment step is unnecessary for the magnetic disk substrate used in

an HDD apparatus of a perpendicular magnetic recording system.

[0040]

The chamfered surface 14 of the outer edge of the glass substrate 1 can satisfy the above-described conditions by chamfering the outer edge of the glass substrate 1 with an apparatus shown in Fig. 4. That is, as shown in Fig. 4, the portion to be chamfered on one side of the glass substrate 1 is polished by abutting the glass substrate 1 against a polishing body 31 that is supported by a rotating shaft 32 being rotatable in the direction shown by the arrow and has a spherical concave equipped with polishing cloth so that the portion to be chamfered is in simultaneous contact with the polishing cloth over the whole circumference; and relatively moving the polishing body 31 and the glass substrate 1 while pressing the portion to be chamfered of the one side of the glass substrate 1 against the polishing cloth so that the portion to be chamfered is in simultaneous contact with the polishing cloth over the whole circumference. The present applicant has proposed such polishing technologies (Japanese Patent Application Nos. 2006-237515 and 2006-237879). The entire contents thereof are incorporated herein by reference.

[0041]

Alternatively, the conditions can be accomplished by keeping the rotation axis of laminate of the glass substrate and the rotation axis of polishing member (polishing brush or polishing pad) parallel to each other and the distance therebetween constant during the end surface polishing step. On this occasion, the rotation axis of laminate of the glass substrate agrees with the central axis of the glass substrate constituting the laminate. Furthermore, the conditions can be accomplished by, in the chamfering step, controlling the holding accuracy (reduction in the inclination of the substrate surface from the horizontal direction) of the apparatus holding the glass substrate 1 and grinding conditions such as the type and the diameter of abrasive grains used for

grinding, load, surface plate rotation speed, and polishing liquid flow rate.

[0042]

The conditions of the crossing points in the magnetic disk substrate according to the present invention are preferred in substrates having a size of 3.5 inches or less (in particular, 2.5 inches and 1.8 inches). Furthermore, the machining of a glass substrate is difficult compared to an aluminum alloy substrate, and it is difficult to keep the shape constant. Therefore, the above-mentioned conditions are most important.

[0043]

Next, a magnetic disk produced by using the magnetic disk substrate according to the present invention will be described. The magnetic disk according to the present invention is constituted by forming at least a magnetic layer on the glass substrate described above.

[0044]

The magnetic disk is usually produced by laminating a foundation layer, a magnetic layer, a protective layer, and a lubricating layer in series on a glass substrate 1 having a surface provided with chemical strengthening treatment according need. The foundation layer in the magnetic disk is properly selected depending on the magnetic layer.

[0045]

The material constituting the foundation layer is, for example, at least one selected from nonmagnetic materials such as Cr, Mo, Ta, Ti, W, V, B, and Al. In the magnetic layer whose main component is Co, the foundation layer is preferably made of single Cr or a Cr alloy from the viewpoints of, for example, improvement in magnetic characteristics. In addition, the foundation layer is not limited to a single layer and may have a multilayer structure in which the same or different types of layers are laminated. Examples of the multilayer foundation layer include Cr/Cr, Cr/CrMo, Cr/CrV, CrV/CrV, Al/Cr/CrMo, Al/Cr/Cr,

Al/Cr/CrV, and Al/CrV/CrV layers.

[0046]

Examples of the material constituting the magnetic layer include materials whose main component is Co, such as CoPt, CoCr, CoNi, CoNiCr, CoCrTa, CoPtCr, and CoNiPt, and CoNiCrPt, CoNiCrTa, CoCrTaPt, and CoCrPtSiO. The magnetic layer may have a multilayer structure in which a nonmagnetic film (for example, Cr, CrMo, or CrV) divides a magnetic film (for example, CoPtCr/CrMo/CoPtCr or CoCrTaPt/CrMo/CoCrTaPt) with for reducing noise.

[0047]

The material for a magnetic layer applicable to a magnetoresistance effect head (MR head) or a giant magnetoresistance effect (GMR head) may be a Co-based alloy containing an impurity element selected from Y, Si, rare-earth elements, Hf, Ge, Sn, and Zn or an oxide of these impurity elements. Furthermore, in addition to the above, the magnetic layer may be a granular film having a structure in which magnetic particles of, for example, Fe, Co, FeCo, or CoNiPt are dispersed in a ferrite-based or iron-rare earth element-based nonmagnetic film or in a nonmagnetic film made of, for example, SiO₂ or BN.

[0048]

Examples of the material constituting the protective layer include Cr, Cr alloys, carbon, zirconium, and silica. Such a protective film can be formed subsequently after the formation of the foundation layer and the magnetic layer with an in-line type sputtering apparatus. Furthermore, the protective film may be a single layer or have a multilayer structure of the same or different types of films. In addition, another protective layer may be formed on the protective layer or instead of the protective layer. For example, instead of the above-mentioned protective layer, a silicon oxide (SiO₂) film may be formed by diluting tetraalkoxysilane with an alcohol-based solvent, dispersing colloidal silica microparticles therein, applying the dispersion onto a Cr film, and firing the

resulting film.

[0049]

The lubricating layer is formed by, for example, diluting perfluoropolyether (PEPE) serving as a liquid lubricating agent in, for example, a freon-based solvent; applying the lubricating agent to the surface of a medium by dipping, spin-coating, or spraying; and carrying out heat treatment according to need.

[0050]

Fig. 5 is an exploded diagram schematically showing an HDD apparatus (load/unload system) having the magnetic disk described above. The HDD apparatus includes at least one magnetic disk and a magnetic head for carrying out data recording and/or reproduction for the magnetic disk. That is, as shown in Fig. 5, the HDD apparatus is constituted by fitting the hole of a magnetic disk 44 to a spindle motor 43 of a pedestal 42 having a circuit board 41 and the spindle motor 43 and installing a bottom coil motor constituted with a head assembly 46 held between a bottom yoke 45 and a magnet 47 and a top yoke 48. In the HDD apparatus, the head moves to a recording region (main surface) of the magnetic disk 44 during a data recording/reproduction operation and is withdrawn from the recording region (main surface) through the outer edge of the magnetic disk 44 at the time of stopping (load/unload system).

[0051]

The satisfaction of the above-described conditions by the positions of crossing points is very effective for a magnetic disk substrate mounted on an HDD apparatus in which the floating amount of the head is reduced. For example, the satisfaction is very effective for a magnetic disk substrate for an HDD apparatus of a system in which the magnetic head is loaded on and unloaded from the main surface of a magnetic disk through the outer edge of the magnetic disk, a magnetic disk substrate for an HDD apparatus in which a magnetic disk is rotated at least at a rotation speed of 7200 rpm, a magnetic

disk substrate having a touch-down height of 4 nm or less, and a magnetic disk substrate having a recording density of 200 Gbit/inch² or more.

[0052]

Examples performed for making the effects of the present invention clear will be described below.

[0053]

(Examples 1 to 3)

(1) Shape processing step and first lapping step

First, molten aluminosilicate glass was molded into a disk shape by direct press using upper, lower, and rim dies to give an amorphous glass plate. Here, chemical strengthening glass was used as the aluminosilicate glass. The resulting disk-shaped glass plate had a diameter of 68 mm and a thickness of 1 mm.

[0054]

Then, the glass plate was subjected to lapping of both main surfaces to give a disk-shaped glass base material. This lapping step was carried out using alumina-based loose grains with a both-sides lapping machine employing a planetary gear mechanism. Specifically, the lapping was performed by pressing lapping plates onto both surfaces of the glass plate, supplying grinding liquid containing the loose grains onto the main surfaces of the glass plate, and relatively moving them. The lapping step provided flat main surfaces to the glass base material. In addition, the lapping step reduced the thickness of the glass base material to 0.7 mm.

[0055]

(2) End shape forming step (coring and chamfering)

Then, the glass base material was cut with a diamond cutter to cut out glass substrates from the glass base material. Subsequently, a hole was formed at the center of each glass substrate with a cylindrical core drill to form

an annular glass substrate (core ring). On this occasion, two core drills were used for forming the hole from both surfaces of the glass substrate. Then, the outer circumferential end was ground by a diamond grinding wheel using the apparatus shown in Fig. 4 for a predetermined chamfering (chamfering). Furthermore, the inner circumferential end was ground by a diamond grinding wheel using a known apparatus (not shown) for a predetermined chamfering.

[0056]

(3) Mirror polishing step

Then, the end surface of the glass substrate was mirror-polished by a brush polishing method. On this occasion, slurry containing cerium oxide abrasive grains (loose abrasive grains) was used as the polishing abrasive grains. The inner circumferential end was mirror-polished by a magnetic polishing method. The glass substrate after the mirror polishing was washed with water. The mirror polishing step gave the ends of the glass substrate a specular condition that can prevent dust such as particles. As a result, the glass substrate had a diameter of 65 mm and could be used as a substrate for 2.5-inch magnetic disk.

[0057]

(4) Second lapping step

Then, the both main surfaces of the resulting glass substrate were subjected to a second lapping step as in the first lapping step. By subjecting to the second lapping step, fine asperities formed on the main surfaces in the prior steps, i.e., in the end shape forming step and the mirror polishing step, can be removed before the successive polishing step. Therefore, the polishing of the main surfaces can be completed within a short period of time.

[0058]

(5) Main surface polishing step

As the main surface polishing step, first, a first polishing step was

performed. The first polishing step was mainly intended to remove scratches and deformations remaining on the main surfaces without being removed in the lapping step. In the first polishing step, the main surfaces were polished using a hard polishing pad with a both-sides polishing machine employing a planetary gear mechanism. Cerium oxide abrasive grains were used as the abrasive. Furthermore, the glass substrate after the first polishing step was washed by being immersed in neutral detergent, pure water (1), pure water (2), IPA (isopropyl alcohol), and IPA (steam drying) in each washing tank in series.

[0059]

Subsequently, as the main surface polishing step, a second polishing step was performed. The second polishing step was intended to perform mirror finishing of the main surfaces. In the second polishing step, the main surfaces were mirror-polished using a soft polishing pad with a both-sides polishing machine employing a planetary gear mechanism. Cerium oxide abrasive grains that were finer than the cerium oxide abrasive grains used in the first polishing step were used as the abrasive. Furthermore, the glass substrate after the second polishing step was washed by being immersed in neutral detergent (1), neutral detergent (2), pure water (1), pure water (2), IPA (isopropyl alcohol), and IPA (steam drying) in each washing tank in series. Here, each washing tank was applied with ultrasound.

[0060]

(6) Chemical strengthening step

Then, the glass substrate after the lapping step and the polishing step was subjected to chemical strengthening. The chemical strengthening was performed by immersing the washed glass substrate for about 4 hours in a chemical strengthening solution prepared by mixing potassium nitrate (60%) and sodium nitrate (40%) and heated to 380 °C. The immersion was carried out in the condition that a plurality of the glass substrates were being held in a

holder at the end surfaces so that the surfaces of the glass substrates are entirely chemically strengthened.

[0061]

By thus immersing the glass substrates in the chemical strengthening solution, lithium ions and sodium ions in the surface layers of the glass substrates are respectively substituted by sodium ions and potassium ions in the chemical strengthening solution to strengthen the glass substrates. The compressive stress layer formed on the surface layer of each glass substrate had a thickness of about 100 μm .

[0062]

The glass substrate after the chemical strengthening treatment was cooled rapidly by being immersed in a water tank at 20 °C for about 10 minutes. Subsequently, the glass substrate after the rapid cooling was washed by being immersed in concentrated sulfuric acid heated to about 40 °C. Furthermore, the glass substrate after the washing with sulfuric acid was washed by being immersed in pure water (1), pure water (2), IPA (isopropyl alcohol), and IPA (steam drying) in each washing tank in series. Here, each washing tank was applied with ultrasound.

[0063]

Thus, flat, smooth, and highly rigid glass substrates for magnetic recoding media were obtained by performing the first lapping step, the end shape forming step, the mirror polishing step, the second lapping step, the main surface polishing step (first and second polishing steps), the precision cleaning, and the chemical strengthening step.

[0064]

The thus obtained glass substrates (Examples 1 to 3) were investigated for the positions of crossing points CP in the main surfaces of the glass substrates 1 in the planar view of the main surfaces using a contact probe-type

surface shape measuring instrument. The results are shown in Fig. 6.

Furthermore, the distances t (crossing point spaces) from crossing points to the projected points of the crossing points onto the chamfered surfaces 14 were investigated for the positions in the main surfaces of the glass substrates 1 in the planar view of the main surfaces. The results are shown in Fig. 7.

[0065]

As obvious from Fig. 6, in the glass substrates of Examples 1 to 3, the variations in the positions of crossing points in the main surfaces were 0.192 mm, 0.275 mm, and 0.340 mm and were thus significantly small. That is, the circularity of a circle formed by the crossing points was 0.5 mm or less.

Furthermore, as obvious from Fig. 7, in the glass substrates of Examples 1 to 3, the variations in the positions of crossing point spaces in the main surfaces were 0.003 mm, 0.004 mm, and 0.002 mm and were thus significantly small. That is, the variation in the crossing point spaces was 5 μm (0.005 mm) or less.

[0066]

(Comparative Examples 1 and 2)

Glass substrates for magnetic recording media were produced as in Examples 1 to 3 except that in the chamfering step, the outer circumferential end and the inner circumferential end were ground by a diamond grinding wheel using a known apparatus (not shown) for chamfering. The thus obtained glass substrates (Comparative Examples 1 and 2) were investigated for the points of crossing points CP in the main surfaces of the glass substrates 1 in a planar view of the main surfaces and the positions of crossing point spaces, as in Examples 1 to 3. The respective results are shown in Figs. 6 and 7.

[0067]

As obvious from Fig. 6, in the glass substrates of Comparative Examples 1 and 2, the variation in the positions of crossing points in the main surfaces were 0.608 mm and 0.694 mm and were thus large. That is, the circularity of a

circle formed by the crossing points was higher than 0.5 mm. Furthermore, as obvious from Fig. 7, in the glass substrates in Comparative Examples 1 and 2, the variations in the positions of crossing point spaces in the main surfaces were both 0.006 mm and were thus large. That is, the variation in the crossing point spaces was higher than 5 μ m (0.005 mm).

[0068]

Then, the relationship between variations in the positions of crossing points and head crashes was investigated. Here, the glass substrates obtained as in above were subjected to texture treatment and precision cleaning. Then, a foundation layer, a magnetic layer, a protective layer, and a lubricating layer were laminated in series on each glass substrate to produce a magnetic disk. The magnetic disk was mounted on an HDD apparatus of a load/unload system for investigating the incidence rate of head crashes. Here, the term "head crash" refers to that obtained by dividing the number of disks having scratches by the total number when the outer edges were observed every 100 times whether scratches occurred in seek head repeating test (movement of hole $\rightarrow$ outer edge $\rightarrow$ hole) using 1000 drive testers. Herein, the investigation was performed at head floating heights of 7 nm, 10 nm, 12 nm, and 15 nm. The results are shown in Fig. 8.

[0069]

As obvious from Fig. 8, when the variation in the positions of crossing points is 0.5 mm or less, head crashes hardly occur regardless of the head floating height. Therefore, it was confirmed that head crashes can be prevented at a very high rate of success by using the glass substrates of Examples 1 to 3. On the other hand, when the variation in the positions of crossing points is higher than 0.5 mm, the rate of head crashes is increased. In particular, the head crash rate is significantly increased with a decrease in the head floating height. Thus, it was confirmed that head crashes cannot be

sufficiently prevented in the glass substrates of Comparative Examples 1 and 2.

[0070]

The present invention is not limited to the above embodiment and can be suitably modified for application. For example, the number and size of each member and treatment procedures in the above embodiment are illustrative only and can be variously modified for application, as long as the effects of the present invention are achieved. Furthermore, the present invention can be suitably modified in other aspects for application within a range not departing from the object of the present invention.

CLAIMS

1. A magnetic disk substrate having a substantially flat main surface, an end surface, and a chamfered surface between the main surface and the end surface and having a substantially circular shape, wherein

crossing points at which directions along the main surface and directions along the chamfered surface intersect are located at substantially the same distance from the center of the magnetic disk substrate in a planar view of the main surface over a whole circumference of the magnetic disk substrate.

2. The magnetic disk substrate according to claim 1, wherein projected points of the crossing points onto the chamfered surface in the planar view of the main surface are substantially the same position in a thickness direction of the magnetic disk substrate over the whole circumference of the magnetic disk substrate.

3. A magnetic disk substrate having a substantially flat main surface, an end surface, and a chamfered surface between the main surface and the end surface and having a substantially circular shape, wherein

the circularity of a circle formed by crossing points in a planar view of the main surface is 0.5 mm or less where a first distance is a distance from a center of the magnetic disk substrate to the end surface and where the crossing points are each expressed by an intersection point of a first virtual line that connects points on the main surface at positions spaced from the center at 50% and 80% distances in the first distance and a second virtual line that connects points on the chamfered surface at positions spaced from the end surface at 0.15% and 0.30% distances in the first distance.

4. The magnetic disk substrate according to claim 3, wherein second distances from the crossing points to the projected points of the crossing points onto the chamfered surface in the planar view of the main surface are each 15

μm or less.

5. The magnetic disk substrate according to claim 3 or 4, wherein variation in the second distances is 5 μm or less over a whole circumference of the magnetic disk substrate.

6. The magnetic disk substrate according to anyone of claims 1 to 5, wherein the distance between a center of a circle formed by the crossing points in the planar view of the main surface and a center of the magnetic disk substrate is 1200 μm or less.

7. The magnetic disk substrate according to anyone of claims 1 to 6, wherein the magnetic disk substrate is made of glass.

8. A magnetic disk, comprising:

the magnetic disk substrate according to anyone of claims 1 to 7, and
a magnetic layer provided on the magnetic disk substrate.

9. The magnetic disk according to claim 8, wherein the magnetic disk is mounted on a magnetic disk apparatus of a system in which a magnetic head is loaded on and unloaded from the main surface of the magnetic disk through an outer edge of the magnetic disk.

10. The magnetic disk according to claim 8 or 9, wherein the magnetic disk is mounted on a magnetic disk apparatus in which the magnetic disk is rotated at least at a rotation speed of 7200 rpm.

11. The magnetic disk according to anyone of claims 8 to 10, wherein a touch-down height is 4 nm or less.

12. The magnetic disk according to anyone of claims 8 to 11, wherein a recording density is 200 Gbit/inch² or more.

13. A hard disk drive apparatus, comprising:

the magnetic disk according to anyone of claims 8 to 12, and
a magnetic head for carrying out data recording and/or reproduction for the magnetic disk.