

DESCRIPTION

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

Technical Field

[0001]

This invention relates to a method of manufacturing a magnetic disk to be mounted in a magnetic disk device such as a hard disk drive (HDD) and a method of manufacturing a glass substrate which is for use in manufacturing the magnetic disk.

Background Art

[0002]

A magnetic disk is one of recording media for information processing devices such as a hard disk drive (HDD). The magnetic disk comprises a substrate and thin films, such as a magnetic layer, formed thereon. As the substrate, an aluminum substrate has been used. Recently, however, in response to the pursuit of higher recording densities, the ratio of a glass substrate has been gradually increasing because a space between a magnetic head and a magnetic disk can be reduced as compared with aluminum. The surface of the glass substrate is precision-polished so as to minimize the flying height of the magnetic head, thereby realizing an increase in recording density.

As described above, high smoothness of the surface of the magnetic disk is essential for the reduction in flying height (flying amount) which is necessary for the increase in recording density. In order to obtain high smoothness of the surface of the magnetic disk, a substrate surface having high smoothness is ultimately required. However, a stage has been reached where

the increase in recording density of the magnetic disk is no longer realized only by precision-polishing the surface of the substrate. That is, the high smoothness cannot be obtained even by precision-polishing the surface of the substrate if foreign matter is adhered thereto. Naturally, removal of foreign matter has been conventionally carried out. However, the present situation is that the foreign matter on the substrate, which has conventionally been allowed, becomes a problem according to the current level of increase in density.

[0003]

It is possible to obtain a glass substrate with high smoothness by precision polishing using a cerium oxide-based polisher. However, there is a problem that projecting foreign matter unable to be removed by normal cleaning remains after the polishing process using the cerium oxide-based polisher and thus the surface roughness cannot be reduced. This projecting foreign matter is often formed by the polishing abrasive grains remaining on the substrate. As a technique of removing the projecting foreign matter formed by the adhering cerium oxide abrasive grains, for example, in the technical field of glass substrates for information recording media, it has been proposed to carry out sulfuric acid cleaning after polishing using cerium oxide abrasive grains (Patent Document 1 below). Further, for example, in the technical field of information recording media, liquid crystal or organic EL displays, photomasks, or the like, proposal has been made of a technique of cleaning a glass base member with a cleaning chemical solution containing three components of an acid, a reducing agent, and fluorine ions (Patent Document 2 below).

[0004]

Patent Document 1: Japanese Unexamined Patent Application
Publication (JP-A) No. 2000-348338

Patent Document 2: Japanese Unexamined Patent Application
Publication (JP-A) No. 2004-059419

Disclosure of the Invention

Problem to be Solved by the Invention

[0005]

Recently, an information recording density of 60Gbit/inch² or more has been required in hard disk drives (HDDs). One reason therefor is related to the fact that, HDDs are now mounted in portable telephones, navigation systems, digital cameras, and so on, in addition to conventional needs as computer storage devices.

In the case of these new uses, a housing space for mounting an HDD is extremely small as compared with a computer. Therefore, it is necessary to reduce the size of the HDD. For this purpose, it is necessary to reduce the diameter of a magnetic disk to be mounted in an HDD. For example, a 3.5-inch or 2.5-inch magnetic disk may be employed for use with the computer. On the other hand, in case of the above-mentioned new uses, a smaller-diameter magnetic disk of, for example, 0.8-inch to 1.8-inch is employed. Even in the case where the magnetic disk is reduced in diameter as described above, it is necessary to store a predetermined or more amount of information. Consequently, the improvement in information recording density is accelerated.

[0006]

Further, in order to effectively use the limited disk area, LUL (Load Unload) type HDDs become used in place of the conventional CSS (Contact Start and Stop) type. In the LUL type, a magnetic head is retreated to an inclined platform called a ramp located outside a magnetic disk during stoppage of the HDD. At the time of starting operation, after the magnetic disk starts to rotate, the magnetic head is caused to slide from the ramp and to fly over the magnetic disk to perform recording/reproduction. At the time of stopping operation, the magnetic head is retreated to the ramp outside the magnetic disk

and then the rotation of the magnetic disk is stopped. The sequence of operations mentioned above is called the LUL operation. In the magnetic disk for the LUL type HDD, it is not necessary to provide a region (CSS region) for sliding contact with a magnetic head as opposed to the CSS type and thus it is possible to enlarge a recording/reproducing region, which is preferable for increasing the information capacity.

In order to improve the information recording density under these circumstances, it is necessary to minimize a spacing loss by reducing the flying height of a magnetic head. For achieving an information recording density of 60 gigabits per inch² or more, the flying height of the magnetic head should be set to 10nm or less. In the LUL type, as opposed to the CSS type, it is not necessary to provide convex and concave shapes for CSS on the surface of a magnetic disk and thus it is possible to significantly smooth the surface of the magnetic disk. Accordingly, in the case of the magnetic disk for the LUL type, the flying height of the magnetic head can be much reduced as compared with the CSS type. It is therefore possible to increase the S/N ratio of a recording signal and thus to contribute to the increase in recording capacity of the magnetic disk device.

[0007]

Because of the significant reduction in flying height of the magnetic head following the recent introduction of the LUL type, a magnetic disk is required to stably operate even in the case of an extremely low flying height of 10nm or less. However, when a magnetic head flies over the surface of the magnetic disk with such an extremely low flying height, there has arisen a problem that fly stiction failure frequently occurs. The fly stiction failure is a failure in which the flying posture of a magnetic head suddenly becomes unstable during recording/reproduction to cause an abnormal change in a recording/reproducing signal. This fly stiction failure is particularly liable to

occur in the case of a magnetic head adapted to fly with an NPAB (negative pressure air bearing surface) slider, i.e. a negative pressure slider. The magnetic head having the negative pressure slider is advantageous in that stable flight is achieved even with a low flying height of 10nm or less, but creates a strong vacuum at a bottom surface (i.e. a surface facing a magnetic disk) of the magnetic head. Therefore, the fly stiction failure is liable to occur.

Further, when the flying height of the magnetic head becomes 10nm or less, there has arisen a problem that thermal asperity failure is liable to occur in the case of a magnetic head incorporating a magnetoresistive effect reproducing element, for example, a TMR (tunneling MR, tunneling magneto-resistance) reproducing element. When the thermal asperity failure occurs, the error rate is extremely degraded so that it becomes difficult to perform information recording/reproduction at a predetermined recording density, for example, 60 gigabits per inch² or more.

[0008]

Under these circumstances, the present inventors have endeavored to develop a magnetic disk that is free of the occurrence of crash failure, fly stiction failure, and thermal asperity failure and thus ensures stable recording/reproduction even if a magnetic head flies with a flying height of 10nm or less, and a glass substrate for the magnetic disk. For example, they have endeavored to carry out precision mirror polishing with fine polishing abrasive grains and to compose a cleaning chemical solution to thereby accurately remove the adhered polisher in a subsequent cleaning process. Various cleaning techniques, for example, including the cleaning utilizing the techniques of the foregoing Patent Document 1 and Patent Document 2 were used, but it has been found out that, in some cases, these failures are not prevented reliably.

Such a problem may possibly occur not only on the surfaces (main

surfaces) of a substrate, but also on end faces of the substrate. If foreign matter is adhered on the outer peripheral end face and the inner peripheral end face, thermal asperity is caused to occur due to generation of dust from the end faces of the substrate. Normally, in the manufacture of a magnetic disk, use is made of a disk-shaped (disc-shaped) substrate having a circular hole at its center portion. Since end faces of the substrate are rougher than the main surfaces thereof, a polisher used for end face polishing bites into the end faces and thus is difficult to remove. Further, there is also a case where an abrasive adhered in a grinding process before polishing the end faces of the substrate bites into the end faces. Particularly, in the case of a small-diameter disk, for example, in the case of a 0.8-inch to 1-inch small-diameter magnetic disk, its inner diameter is set to, for example, 7mm or less. It has been found out that, in a substrate of such a small-diameter magnetic disk, particularly the inner periphery is difficult to be cleaned. Therefore, an adhered polisher is difficult to remove and thus is liable to remain as foreign matter. Accordingly, also for the end faces of the substrate, it is an important subject to reliably remove the polisher residue.

[0009]

This invention has been made to solve the above problems and has a first object to provide a method of manufacturing a glass substrate particularly useful for manufacturing a magnetic disk that allows a magnetic head to fly with a low flying height of 10nm or less, and a method of manufacturing a magnetic disk using a glass substrate manufactured by the above-mentioned method.

A second object of this invention is to provide a method of manufacturing a glass substrate particularly useful for manufacturing a magnetic disk whose recorded information is reproduced by a magnetic head incorporating a magnetoresistive effect reproducing element, particularly a TMR (tunneling MR, tunneling magneto-resistance) reproducing element, and a

method of manufacturing a magnetic disk using a glass substrate manufactured by the above-mentioned method.

A third object of this invention is to provide a method of manufacturing a glass substrate particularly useful for manufacturing a magnetic disk to be mounted in a hard disk drive that performs starting and stopping operations of the load unload type, and a method of manufacturing a magnetic disk using a glass substrate manufactured by the above-mentioned method.

A fourth object of this invention is to provide a method of manufacturing a glass substrate particularly useful for manufacturing a magnetic disk adapted for recording/reproduction at a high information recording density of 60 gigabits per inch² or more, and a method of manufacturing a magnetic disk using a glass substrate manufactured by the above-mentioned method.

Means for Solving the Problem

[0010]

In order to solve the foregoing problems, the present inventors have observed in detail, using an atomic force microscope and an electron microscope, the surfaces of a glass substrate for a magnetic disk, which has been mirror-polished with a cerium oxide-based polisher and then cleaned with a cleaning solution containing an acid such as sulfuric acid. Particularly, a very small rectangular region with a side of 5 μ m was enlarged and observed carefully and it was discovered that small holes (concave portions) each having an opening size of about 0.1 μ m to 0.5 μ m and a depth of about 6nm to 8nm were formed on the surface of the glass substrate after the cleaning. Since projecting foreign matter was not observed on this glass substrate, the adhered polishing abrasive grains were considered to be substantially removed, but the very small concave portions were formed. Conventionally, in the case of a glass substrate for a magnetic disk, the main aim was to remove convex foreign

matter that adversely affects a magnetic head flying above. The concave shape was not deemed as a serious problem because of no possibility of collision with the magnetic head above. The present inventors have been convinced that these concave portions caused the foregoing problems. This is because they have considered that, since the flying height of the magnetic head was significantly reduced as compared with conventional technique, the concave portions which were not deemed as a serious problem have come to adversely affect the magnetic head.

Detailed observation was carried out in the same manner also for end faces of the above glass substrate for the magnetic disk. As a result, projecting foreign matter supposed to derive from the residue of polishing abrasive grains was observed and much projecting foreign matter was found particularly on the inner peripheral end face of the substrate.

[0011]

Therefore, the present inventors have made studies paying attention to the following conditions. First, it is possible to maintain a mirror surface state of the mirror-polished surfaces of a glass substrate. Second, it is possible to reliably remove projecting foreign matter (convex portions) formed due to adhesion of a polisher. Third, no opening portion (concave portion) is formed that adversely affects a magnetic head when the magnetic head passes above with a low flying height of 10nm or less. Fourth, also for mirror-polished end faces of the glass substrate, it is possible to reliably remove projecting foreign matter (convex portions) formed due to adhesion of a polisher and to maintain a mirror surface state thereof. Thus, this invention has been completed.

This invention has the following structures.

[0012]

(Structure 1 of the Invention)

A method of manufacturing a glass substrate for a magnetic disk,

which includes mirror polishing and cleaning processes of a glass substrate, the method further comprising supplying to the glass substrate a polisher mainly containing a rare earth oxide and having a fluorine content of 5wt% or less, mirror-polishing an end face of the glass substrate by relatively moving a polishing cloth and the glass substrate to each other, and then bringing the glass substrate into contact with a cleaning solution containing ascorbic acid, fluorine ions, and 3wt% or more sulfuric acid to thereby dissolve and remove the polisher.

Herein, the fluorine content is a content of fluorine atoms contained in the polisher. The fluorine atoms are contained in the polisher in the form of a fluorine-containing substance (fluoride and/or fluorine).

In Structure 1 of the Invention, the concentration of the sulfuric acid contained in the cleaning solution may be preferably set to 4wt% or more. Further, the concentration of the sulfuric acid contained in the cleaning solution may be preferably set to 10wt% or less.

The end face of the glass substrate is a surface formed between the front and back main surfaces of the glass substrate and substantially perpendicular to the main surfaces. For example, in the case of a disk-shaped glass substrate having a circular hole at its center portion, the end face represents an outer or inner peripheral end face.

[0013]

(Structure 2 of the Invention)

The method according to the structure 1, wherein a concentration of the ascorbic acid contained in the cleaning solution is set to 0.1wt% or more.

The concentration of the ascorbic acid contained in the cleaning solution may be preferably set to 0.5wt% or more. Further, the concentration of the ascorbic acid contained in the cleaning solution may be preferably set to 3wt% or less.

(Structure 3 of the Invention)

The method according to the structure 1 or 2, wherein a content of the fluorine ions contained in the cleaning solution is set to 1ppm or more and 40ppm or less.

The content of the fluorine ions contained in the cleaning solution can be preferably set to 3ppm or more and 20ppm or less.

[0014]

(Structure 4 of the Invention)

The method according to any one of the structures 1 to 3, wherein a glass forming the glass substrate is an amorphous aluminosilicate glass mainly containing 58wt% or more and 75wt% or less SiO_2 , 5wt% or more and 23wt% or less Al_2O_3 , 3wt% or more and 10wt% or less Li_2O , and 4wt% or more and 13wt% or less Na_2O .

(Structure 5 of the Invention)

The method according to any one of the structures 1 to 4, wherein the end face of the glass substrate after the cleaning process is a mirror surface having a maximum valley depth R_v of 4nm or less.

Preferably, the end face may be a mirror surface with 6nm or less in maximum roughness R_{max} .

[0015]

(Structure 6 of the Invention)

A method of manufacturing a magnetic disk, the method comprising forming at least a magnetic layer on the glass substrate manufactured by the method according to any one of the structures 1 to 5.

(Structure 7 of the Invention)

The method according to the structure 6, wherein the magnetic disk adapted to record/reproduce information is manufactured at a bit recording density of 60 gigabits per inch^2 or more.

In this invention, $R_{\max}$ represents a maximum roughness calculated in accordance with the Japanese Industrial Standard (JIS) B0601. When an average plane of the surface roughness (i.e. the surface shape) is given as a reference plane, $R_{\max}$ is the sum of an absolute value of the height to the highest peak as seen from the reference plane (this is called a maximum peak height R_p) and an absolute value of the depth to the deepest valley as seen from the reference plane (this is called a maximum valley depth R_v). That is, the maximum roughness can be calculated as $R_{\max}=R_p+R_v$. Further, in this invention, the surface roughness (e.g. maximum roughness $R_{\max}$, maximum peak height R_p , maximum valley depth R_v , arithmetic average roughness R_a) is preferably a surface roughness of the surface shape obtained when measured by an atomic force microscope (AFM). For example, the surface roughness is preferably for the the surface shape obtained when a square region of $5\mu\text{m}$ long and $5\mu\text{m}$ wide is measured for each of the surfaces and end faces of a substrate.

Effect of the Invention

[0016]

This invention is, for example, a method of manufacturing a glass substrate for a magnetic disk, including a mirror polishing process and a cleaning process of a glass substrate, and is characterized by supplying to the glass substrate a polisher mainly containing a rare earth oxide and having a fluorine content of 5wt% or less, mirror-polishing an end face of the glass substrate by relatively moving a polishing cloth and the glass substrate to each other, and then bringing the glass substrate into contact with a cleaning solution containing ascorbic acid, fluorine ions, and 3wt% or more sulfuric acid to thereby dissolve and remove the polisher. Therefore, the end face of the glass substrate after the cleaning is free of formation of a concave portion that

adversely affects a magnetic head flying with a flying height of, for example, 10nm or less, projections formed thereon due to adhesion of the polisher are removed, and the end face of the glass substrate is a mirror surface.

Therefore, in a magnetic disk manufactured using this glass substrate, it is possible to prevent the occurrence of head crash failure, thermal asperity failure, and fly stiction failure.

[0017]

Accordingly, it is possible to provide a method of manufacturing a glass substrate particularly useful for manufacturing a magnetic disk whose recorded information is reproduced by a magnetic head incorporating a magnetoresistive effect reproducing element, particularly a TMR (tunneling MR, tunneling magneto-resistance) reproducing element, and a method of manufacturing a magnetic disk using a glass substrate manufactured by the above-mentioned method. Further, it is possible to provide a method of manufacturing a glass substrate particularly useful for manufacturing a magnetic disk to be mounted in a hard disk drive that performs starting and stopping operations of the load unload type, and a method of manufacturing a magnetic disk using a glass substrate manufactured by the above-mentioned method. Further, it is possible to provide a method of manufacturing a glass substrate particularly useful for manufacturing a magnetic disk adapted for recording/reproduction at a high information recording density of 60 gigabits per inch² or more, and a method of manufacturing a magnetic disk using a glass substrate manufactured by the above-mentioned method.

Further, it is possible to provide a method of manufacturing a glass substrate particularly useful for manufacturing a magnetic disk whose recorded information is reproduced by a magnetic head adapted to fly with an NPAB slider, i.e. a negative pressure slider, and a method of manufacturing a magnetic disk using a glass substrate manufactured by the above-mentioned

method.

Best Mode for Carrying Out the Invention

[0018]

Hereinbelow, an embodiment of this invention will be described in detail.

The present inventors composed various cleaning reagents and compared them for solubility to cerium oxide (cerium dioxide) which is a main component of a polisher, and confirmed that a treatment solution containing sulfuric acid and ascorbic acid exhibited a good solubility. Particularly, it was confirmed that, when hydrofluoric acid or sodium fluoride was added as an additive to a treatment solution containing sulfuric acid and ascorbic acid to thereby supply fluorine ions, the quick solubility was obtained. By examining the solubility to rare earth oxides, other than cerium oxide, such as lanthanum oxide, praseodymium oxide, and neodymium oxide, it was confirmed that the solubility equivalent to that to cerium oxide was obtained. Actually, mirror polishing of a glass substrate was performed using a polishing solution containing a cerium oxide-based polisher and then cleaning was performed using a cleaning solution containing sulfuric acid, ascorbic acid, and fluorine ions. Then, it was possible to remove projections (convex portions) formed due to adhesion of the polisher to the glass substrate regardless of the concentration of sulfuric acid.

[0019]

However, when the surface was observed in detail using an atomic force microscope, it was discovered that small holes (concave portions) were formed on the surface of the glass substrate in the case where the glass substrate was brought into contact with a cleaning solution in which the sulfuric acid concentration was lower than a predetermined concentration. Specifically, it was found out that the concave portions were formed on the surface of the

glass substrate when the sulfuric acid concentration was less than 3wt%. It is considered that, in a cleaning solution of the type where sulfuric acid, ascorbic acid, and fluorine ions coexist, when the sulfuric acid concentration becomes lower than 3wt%, the sulfuric acid exerts a leaching action on a glass, thereby deteriorating the surface thereof to increase the surface roughness. The leaching is a phenomenon that, in a multicomponent glass such as an aluminosilicate glass, a substance soluble to an acid contained in the glass is dissolved out while maintaining a glass framework portion (SiO framework). The leaching is a phenomenon that significantly occurs in a multicomponent glass containing elements in addition to SiO. The leaching is a phenomenon different from etching in which a glass itself is dissolved.

Therefore, it has been found out that, in order to prevent the formation of concave portions on the surface of a glass substrate to thereby achieve the objects of this invention, it is necessary that, in a cleaning solution of the type where sulfuric acid, ascorbic acid, and fluorine ions coexist, the sulfuric acid be contained in an amount of at least more than 1.5wt% and particularly of 3wt% or more.

[0020]

Further, the present inventors carried out cleaning of glass substrates using this cleaning solution and found that the manner of formation of convex portions and concave portions on the glass substrate differed depending on the kind of cerium oxide-based polisher. Although collectively called a cerium oxide-based polisher for use in mirror polishing of a glass substrate, there are many kinds of polishers depending on manufacturing methods and so on. Further, in a cerium oxide-based polisher, although cerium oxide is a main component, rare earth oxides, other than cerium oxide, such as, for example, lanthanum oxide, praseodymium oxide, and neodymium oxide, are also contained. That is, the cerium oxide-based polisher is a rare earth

oxide-based polisher containing cerium oxide as the main component.

Currently (as of A.D. 2005), cerium oxide-based polishers that are relatively easily obtainable can be classified into two kinds, i.e. a cerium oxide-based polisher manufactured by using, as a raw material, a bastnaesite ore containing fluorine-containing substances and carrying out a treatment such as calcination, and a cerium oxide-based polisher manufactured by using a refined rare earth compound as a raw material and carrying out a treatment such as calcination. The former cerium oxide-based polisher contains fluorine mainly in the form of rare earth fluorides since the raw material ore itself contains the fluorine-containing substances. On the other hand, the latter cerium oxide-based polisher does not contain fluorine or contains only a little if any. The fluorine content in the polisher may be measured as a content of fluorine atoms by XPS (X-ray photoelectron spectroscopy) or the like.

[0021]

For the cleaning solution according to this invention of the type where sulfuric acid (sulfuric acid concentration was 3wt% or more), ascorbic acid, and fluorine ions coexist, the cleaning abilities with respect to cerium oxide-based polishers with various fluorine contents obtained as described above were compared with each other. As a result, it was found out that, in the case of the polisher in which the fluorine content exceeded a predetermined content, convex portions formed on the surface of a glass substrate could not be removed as expected. Further, it was found out that, in some cases, concave portions were formed in the case of the polisher in which the fluorine content exceeded the predetermined content.

From this point of view, it was found out that, when cleaning a glass substrate for a magnetic disk using the cleaning solution of this invention, it is necessary that a cerium oxide-based polisher (i.e. a rare earth oxide-based polisher) adhering on the surface of the glass substrate not contain fluorine or,

even if it is a fluorine-containing polisher, the content of fluorine be 5wt% or less.

[0022]

The cerium oxide-based polisher with the high fluorine content contains a large amount of rare earth fluorides such as cerium fluoride in addition to rare earth oxides such as cerium oxide. It is supposed that, when the polisher is brought into contact with the cleaning liquid containing sulfuric acid, mainly the cerium fluoride and the sulfuric acid are reacted with each other to produce hydrofluoric acid and cerium sulfate. In parallel, the cerium oxide and the sulfuric acid are reacted with each other to produce water and cerium sulfate. It is believed that the reactions in which the cerium fluoride and the sulfuric acid are reacted with each other to produce the hydrofluoric acid and the cerium sulfate are more predominant. That is, it is believed that, when fluorine exceeding the predetermined amount is contained in the rare earth oxide-based polisher, dissolution of the rare earth oxides as the main component of the polisher is inhibited due to reasons such as the occurrence of the reactions between the rare earth fluorides as impurities and the sulfuric acid. Therefore, it is believed that the convex portions formed on the glass substrate due to adhesion of the polisher cannot be suitably removed.

As a result of the reactions between the rare earth fluorides and the sulfuric acid, the hydrofluoric acid is produced in the cleaning solution. Due to the hydrofluoric acid thus produced, the concentration of fluorine ions in the cleaning solution may possibly be disturbed to be greater than a desired concentration. Further, if hydrofluoric acid is produced near the interface between the polisher adhered on the glass substrate and the glass, the surface of the glass substrate may possibly be etched in very small regions (formation of concave portions) due to the hydrofluoric acid produced as mentioned above.

[0023]

In this invention, use is made of a low-fluorine polisher in which the fluorine content is 5wt% or less. Therefore, without causing the foregoing problems, it is possible to manufacture a mirror-surface glass substrate without formation of a convex or concave portion.

In this invention, if the concentration of sulfuric acid contained in a cleaning solution for a glass substrate is set to 3wt% or more, it is possible to suppress the formation of a concave shape on the surface of the glass substrate. However, for example, in view of increasing the dissolution rate of a polisher to improve the production efficiency, the sulfuric acid concentration may be practically set to 4wt% or more. As the sulfuric acid concentration is increased, the production efficiency is enhanced. However, the concentration exceeding 30wt% is not preferable because the dissolution rate of cerium oxide is reduced conversely. From this point of view, the sulfuric acid concentration is preferably set to 30wt% or less. Further, in the case of a fluorine-containing cerium oxide-based polisher, the reactions between rare earth fluorides and sulfuric acid occur as described above. Therefore, it is not preferable to excessively increase the sulfuric acid concentration. From this point of view, the sulfuric acid concentration is preferably set to 30wt% or less and particularly 10wt% or less.

[0024]

In this invention, ascorbic acid contained in a cleaning solution for a glass substrate may be L-ascorbic acid or may be supplied as a salt of L-ascorbic acid. The concentration of ascorbic acid contained in the cleaning solution may be adjusted within a range where, as the cleaning solution, a predetermined solubility to a polisher can be maintained, and, for example, may be set to 0.1wt% or more. If the concentration becomes less than 0.1wt%, there is a case where the polisher dissolution rate is reduced so that the product efficiency is lowered. In consideration of the production rate, the concentration

is preferably set to 0.5wt% or more and particularly 1wt% or more. Although no particular limitation is necessary for the upper limit of the ascorbic acid concentration, the concentration may be practically set to 4wt% or less. However, since the concentration of around 4wt% is close to the saturation concentration of ascorbic acid, it is practically difficult to compose a cleaning solution. Therefore, 3wt% or less is preferable in consideration of the production efficiency. Since the composition of a cleaning solution can be quickly performed at the concentration of around 3wt%, it is possible to improve the production efficiency.

[0025]

In this invention, fluorine ions contained in a cleaning solution for a glass substrate are preferably supplied by adding hydrofluoric acid or sodium fluoride to the cleaning solution. It is particularly preferable to use hydrofluoric acid. The concentration of fluorine ions may be adjusted to a predetermined value within a range where the action of this invention is obtained, and is preferably set to 1ppm or more. If the fluorine ion concentration is less than 1ppm, the dissolution rate of the cleaning solution to a polisher is slow. Therefore, the production efficiency is lowered and the solubility to the polisher may be insufficient in some cases. From this point of view, it is particularly preferable to set the fluorine ion concentration to 3ppm or more. It is recommended that the upper limit of the fluorine ion concentration be set to 40ppm or less and particularly 20ppm or less. If the concentration exceeds 40ppm, the dissolution rate of the cleaning solution to the polisher is slow. Therefore, the production efficiency is lowered and the solubility to the polisher may be insufficient in some cases. Further, if the fluorine concentration exceeds 40ppm, an etching action may possibly be exerted on the glass substrate. If the etching action is exerted on the glass substrate, there is a possibility that the roughness of the mirror-polished surface of the glass

substrate increases and, further, convex and concave shapes are formed on the surface of the glass substrate.

In the case of the fluorine-containing cerium oxide-based polisher, hydrofluoric acid is produced due to the reactions between rare earth fluorides and sulfuric acid contained in the cleaning solution as described above. Therefore, in this invention, the sulfuric acid concentration should be controlled at the ppm level. Particularly, if fluorine contained in the polisher exceeds 5wt%, it may become difficult to control the concentration of fluorine ions in the cleaning solution.

[0026]

In this invention, a polisher for use in mirror polishing of a glass substrate is not particularly limited as long as the polisher mainly contains a rare earth oxide and has a fluorine content of 5wt% or less. Particularly, a cerium oxide-based polisher containing cerium oxide as a main component is preferable. Herein, the polisher mainly containing a rare earth oxide and having a fluorine content of 5wt% or less is a polisher mainly containing a rare earth oxide and containing no fluorine or, even if it is a fluorine-containing polisher, having the fluorine content of 5wt% or less. The fluorine content is a content of fluorine atoms contained in the polisher. The fluorine atoms are contained in the polisher in the form of a fluorine-containing substance (fluoride and/or fluorine). In the case of containing fluorine in the polisher, the fluorine content is preferably set to 3wt% or less.

[0027]

There is no particular limitation to a method of mirror polishing in this invention. For example, a glass substrate and a polishing cloth are brought into contact with each other and, while supplying a polisher, the polishing cloth and the glass substrate are relatively moved to each other, thereby polishing at least an end face of the glass substrate into a mirror surface. A polishing pad

may be used as the polishing cloth. The polishing pad is preferably a polishing pad for a soft polisher. The hardness of the polishing pad is preferably set to 60 or more and 80 or less in Asker C hardness. A contact surface of the polishing pad, which is to be contacted with the glass substrate, is preferably made of a foamed resin formed with foam pores, particularly polyurethane foam. The average grain size of polishing abrasive grains (in the case of this invention, polishing abrasive grains mainly containing cerium oxide) contained in the polisher may be set to $0.1\mu\text{m}$ or more and $1\mu\text{m}$ or less. By performing the polishing in this manner, it is possible to polish the end face of the glass substrate into a smooth mirror surface.

[0028]

It is particularly preferable that the mirror polishing treatment and the cleaning treatment according to this invention be applied to an end face of a substrate. If foreign matter is adhered on (outer and inner peripheral) end faces of the substrate, thermal asperity is caused to occur due to generation of dust from the end faces of the substrate. Normally, in the manufacture of a magnetic disk, use is made of a disk-shaped (disc-shaped) substrate having a circular hole at its center portion. Since end faces of the substrate are rougher than the main surfaces thereof, a polisher used for end face polishing bites into the end faces and thus is difficult to remove. Further, there is also a case where an abrasive adhered in a grinding process before polishing the end faces of the substrate bites into the end faces. Therefore, applying this invention to the mirror polishing and cleaning treatments of at least the end faces of the substrate makes it possible to reliably remove the polisher residue on the end faces and is thus preferable. Accordingly, since the generation of dust of the foreign matter such as the polisher from the end faces of the substrate can be prevented, it is possible to reliably prevent thermal asperity.

[0029]

This invention is particularly suitable for a glass substrate for a small-diameter magnetic disk. In the case of a small-diameter disk, for example, in the case of a 0.8-inch to 1-inch small-diameter magnetic disk, its inner diameter is set to, for example, 7mm or less. In a substrate of such a small-diameter magnetic disk, particularly an inner peripheral end face is difficult to be cleaned. Therefore, an adhered polisher is difficult to remove and thus is liable to remain as foreign matter. However, according to this invention, even in the glass substrate for the small-diameter magnetic disk, it is advantageously possible to reliably remove residue of the polisher on the end faces (particularly the inner peripheral end face) of the substrate.

There is no particular limitation to the surface state of an end face of a substrate to which this invention is applied, but it is preferable to apply this invention to an end face having a surface roughness Ra of preferably $1\mu\text{m}$ or less, particularly preferably $0.5\mu\text{m}$ or less, and further preferably $0.05\mu\text{m}$ or less. Further, it is preferable to apply this invention to an end face of a substrate which has been subjected to a mirror polishing treatment.

Although it is preferable to apply this invention to mirror polishing and cleaning treatments of particularly end faces of a substrate, it is of course also preferable to apply this invention to mirror polishing and cleaning treatments of the main surfaces of the substrate.

[0030]

In this invention, a glass forming a glass substrate is preferably an amorphous aluminosilicate glass. The surface of such a glass substrate may be finished to a smooth mirror surface by mirror polishing. As such an aluminosilicate glass, use may be made of an aluminosilicate glass (aluminosilicate glass containing no phosphorus oxide) mainly containing 58wt% or more and 75wt% or less SiO_2 , 5wt% or more and 23wt% or less Al_2O_3 , 3wt% or more and 10wt% or less Li_2O , and 4wt% or more and 13wt% or less

Na₂O. For example, use may be made of an amorphous aluminosilicate glass mainly containing 62wt% or more and 75wt% or less SiO₂, 5wt% or more and 15wt% or less Al₂O₃, 4wt% or more and 10wt% or less Li₂O, 4wt% or more and 12wt% or less Na₂O, and 5.5wt% or more and 15wt% or less ZrO₂, having an Na₂O/ZrO₂ weight ratio of 0.5 or more and 2.0 or less and an Al₂O₃/ZrO₂ weight ratio of 0.4 or more and 2.5 or less, and containing no phosphorus oxide. It is preferable to use a glass containing no alkaline earth metal oxide such as CaO or MgO. As such a glass, N5 Glass (trade name) manufactured by HOYA Corporation is available.

[0031]

An aluminosilicate glass may be subjected to a leaching action due to contact with sulfuric acid so that the surface of a glass substrate is deteriorated resulting in an increase in surface roughness. The cleaning solution according to this invention has the composition prepared taken into account these problems as described before and thus is preferable. In this invention, the end face of the glass substrate after the cleaning treatment is preferably finished to a mirror surface having a maximum valley depth R_v of 4nm or less. This is because, if R_v exceeds 4nm, i.e. the depth of a concave portion is large, the flying posture of a magnetic head flying with a height of about 10nm or less may be disturbed and fly stiction failure may be caused to occur. Further, the substrate is preferably finished to a mirror surface having a maximum roughness R_{max} of 6nm or less. Such a mirror surface state can be realized by carrying out the mirror polishing treatment and the cleaning treatment of this invention in this order.

[0032]

In this invention, it is preferable to perform a chemical strengthening treatment after the cleaning treatment according to this invention. A method of the chemical strengthening treatment is preferably, for example, a

low-temperature ion-exchange method in which ion exchange is performed in a temperature range not exceeding a temperature at a glass transition point, for example, at a temperature of 300°C or more and 400°C or less. The chemical strengthening treatment is a treatment in which a molten chemical strengthening salt and a glass substrate are brought into contact with each other to perform ion exchange between an alkali metal element having a relatively large atomic radius in the chemical strengthening salt and an alkali metal element having a relatively small atomic radius in the glass substrate, thereby causing the alkali metal element having the large ionic radius to penetrate into a surface layer of the glass substrate to thereby produce the compressive stress on the surface of the glass substrate. The chemically strengthened glass substrate is excellent in impact resistance and is particularly suitably mounted, for example, in an HDD for a mobile use. As the **chemical strengthening salt**, use may be preferably made of alkali metal nitrate such as potassium nitrate or sodium nitrate.

[0033]

Since an end face of a glass substrate according to this invention is finished to a mirror surface and is reliably removed of a polisher, it is possible to produce uniform compressive stress on the end face of the glass substrate by performing the chemical strengthening treatment. If the chemical strengthening treatment of the glass substrate is carried out while the polisher is not sufficiently removed, the polisher is fixed to the glass substrate and cannot be easily removed, for example, in the course of ion-exchange treatment at a temperature of 300°C or more and 400°C or less. Further, since the formation of compressive stress is inhibited on a glass just under the adhering polisher, such a portion may possibly be deformed into a convex or concave shape. Since the average grain size of the polisher used in the mirror polishing treatment is about 0.1μm to 1μm, a deformation, such as a convex deformation

or a concave deformation, having a size corresponding thereto may be caused to occur. In this invention, the polisher can be reliably removed and the end face of the glass substrate subjected to the chemical strengthening treatment is a mirror-state smooth surface with no convex or concave shape. Therefore, it is possible to produce uniform compressive stress even in fine regions. Accordingly, even after the chemical strengthening treatment, it is possible to maintain the mirror-state smooth surface with no convex or concave shape.

[0034]

In this invention, a tape polishing treatment may be carried out after the cleaning treatment according to this invention. Since, in this invention, the surface of a glass substrate subjected to the tape polishing treatment is a mirror-state smooth surface with no convex or concave shape, there is no possibility that the surface shape is disturbed due to biting of foreign matter in the tape polishing treatment.

Recently, for the purpose of improving the information recording density of a magnetic disk, there is a case where the magnetic anisotropy along the circumferential direction of the magnetic disk is applied to a magnetic layer of the disk. This is because, since the circumferential direction of the disk is the moving direction of a magnetic head, the application of the magnetic anisotropy along this direction contributes to an increase in recording density. By applying a tape polishing treatment to the surface of a disk-shaped glass substrate, it is possible to form a texture comprising stripes oriented in the circumferential direction of the disk. When a magnetic layer is formed on the glass substrate applied with this texture treatment, it is possible to produce a magnetic anisotropy in the circumferential direction of the disk. For this texture treatment, a diamond polisher is used as a polisher in the tape polishing treatment. By bringing a polishing tape and a glass substrate into contact with each other, supplying a diamond polisher, and relatively moving the polishing

tape and the glass substrate with respect to each other, a texture is formed on the surface of the glass substrate. In this event, if foreign matter is adhered to the surface of the glass substrate or convex or concave shapes are formed thereon, the formation of a desired texture is inhibited. Thus, it becomes difficult to apply a predetermined magnetic anisotropy to a magnetic disk. In this invention, the surface of the glass substrate is a mirror-state smooth surface with no convex or concave shape. Thus, it is possible to form a uniform texture even in fine regions. Therefore, this invention contributes to an increase in recording density of the magnetic disk.

[0035]

In this invention, a magnetic disk is manufactured by forming at least a magnetic layer on a glass substrate according to this invention. As a material of the magnetic layer, use can be made of a CoPt-based ferromagnetic alloy with a hexagonal system having a high anisotropic magnetic field. As a method of forming the magnetic layer, use may be made of a method of forming a magnetic layer on a glass substrate by a sputtering method, for example, a DC magnetron sputtering method. By interposing an underlayer between the glass substrate and the magnetic layer, it is possible to control the orientation direction and size of magnetic grains of the magnetic layer. For example, using an underlayer of a cubic system such as a Cr-based alloy, it is possible to orient an easy magnetization direction of the magnetic layer along the surface of a magnetic disk. In this case, a magnetic disk of the in-plane magnetic recording type is manufactured. On the other hand, using an underlayer of a hexagonal system containing Ru and Ti, it is possible to orient an easy magnetization direction of the magnetic layer along the normal of the surface of a magnetic disk. In this case, a magnetic disk of the perpendicular magnetic recording type is manufactured. The underlayer may be formed by the sputtering method like the magnetic layer.

[0036]

Further, in this invention, a protective layer and a lubricating layer may be formed on the magnetic layer in this order. The protective layer is preferably an amorphous hydrogenated carbon-based protective layer. For example, the protective layer may be formed by a plasma CVD method. The thickness of the protective layer is preferably 30 angstroms to 80 angstroms. As the lubricating layer, use may be made of a lubricant having a functional group at an end of the main chain of a perfluoropolyether compound. Particularly, the lubricant preferably contains, as a main component, a perfluoropolyether compound having a hydroxyl group as a polar functional group at an end. The thickness of the lubricating layer is preferably set to 5 angstroms to 15 angstroms. The lubricating layer may be formed by coating by a dipping method.

A magnetic disk according to this invention is particularly preferable as a magnetic disk for a hard disk drive to be mounted in a mobile device such as a portable telephone, a navigation system, or a digital camera. Further, a glass substrate for a magnetic disk according to this invention is particularly preferable as a glass substrate for the above magnetic disk.

Example

[0037]

Hereinbelow, the method of manufacturing a glass substrate for a magnetic disk and the method of manufacturing a magnetic disk will be described in further detail by citing Examples.

[Example 1]

A method of manufacturing a glass substrate for a magnetic disk according to Example 1 comprises (1) Rough Grinding Process, (2) End Face Mirror Polishing Process, (3) Cleaning Process (Cleaning Process after End Face Mirror Polishing), (4) Lapping Process, (5) First Polishing Process, (6)

Second Polishing Process (Main Surface Mirror Polishing Process), and (7) Chemical Strengthening Process. Hereinbelow, these processes will be described in detail.

[0038]

(1) Rough Grinding Process

At first, a glass disk molded by a press method was ground using relatively rough diamond grindstones. As a glass composition to be a material, use was made of a glass composition mainly containing 62wt% or more and 75wt% or less SiO_2 , 5wt% or more and 15wt% or less Al_2O_3 , 4wt% or more and 10wt% or less Li_2O , 4wt% or more and 12wt% or less Na_2O , and 5.5wt% or more and 15wt% or less ZrO_2 and having an $\text{Na}_2\text{O}/\text{ZrO}_2$ weight ratio of 0.5 or more and 2.0 or less and an $\text{Al}_2\text{O}_3/\text{ZrO}_2$ weight ratio of 0.4 or more and 2.5 or less. This glass composition is a glass containing no phosphorus oxide or no alkaline earth metal oxide such as CaO or MgO . Specifically, use was made of N5 Glass (trade name) which is an amorphous aluminosilicate glass manufactured by HOYA Corporation.

Then, using diamond grindstones with a grain size finer than that of the above grindstones, both surfaces of the glass disk were ground. By this, the surfaces of the glass substrate were finished to a surface roughness of about $10\mu\text{m}$ in R_{max} (measured according to JISB0601). Then, using a cylindrical grindstone, a hole was formed at a center portion of the disk-shaped glass substrate, thereby obtaining a doughnut-shaped glass substrate.

[0039]

(2) End Face Mirror Polishing Process

Then, end faces of the glass substrate were mirror-polished to a surface roughness of $1\mu\text{m}$ in R_{max} and about $0.3\mu\text{m}$ in R_a by brush polishing while rotating the glass substrate. As a polisher, a cerium oxide polisher was used. The amount of fluorine contained in the cerium oxide polisher was analyzed by

XPS (X-ray photoelectron spectroscopy). As a result, the amount was 3wt% in terms of F (fluorine atoms).

[0040]

Then, a cleaning treatment of the glass substrate which has been subjected to the end face mirror polishing process was performed in the manner described below. The glass substrate finished with the polishing process was not subjected to drying (including natural drying), but stored in water and then transferred to the next cleaning process while maintained in the wet state. This is because, if the glass substrate is dried in the state where the polisher residue remains, it may become difficult to remove the polisher by the cleaning treatment.

(3) Cleaning Process (Cleaning Process after End Face Mirror Polishing)

This cleaning process is a cleaning process for removing the polisher remaining on the end faces of the glass substrate finished to mirror surfaces in the mirror polishing process. It is necessary to remove the polisher without roughening the mirror-finished glass surfaces. For example, if a cleaning solution has an etching action or a leaching action with respect to the glass, the mirror-finished glass surfaces are roughened so as to be matte-finished surfaces, not the mirror surfaces. Therefore, a cleaning solution in this invention is composed as a cleaning solution having no etching action or leaching action with respect to the glass, but having selective solubility to specific polishers.

In advance, a cleaning solution containing 4.5wt% sulfuric acid and 1wt% L-ascorbic acid was prepared. Then hydrofluoric acid was added in an amount of 10ppm so as that the content of fluorine ions in this cleaning solution was equal to 10ppm. In this manner, the cleaning solution in this cleaning treatment was composed. The same cerium oxide polisher as that used in the foregoing end face mirror polishing process was dispersed in this cleaning

solution and confirmed to be completely dissolved in about 4 minutes. It was also confirmed that an etching action or a leaching action, otherwise causing a problem on the glass (aluminosilicate glass), was not effected.

[0041]

In the cleaning solution prepared with sulfuric acid and L-ascorbic acid without adding hydrofluoric acid, the dissolution rate of the polisher was slow and about 20 minutes were required for the polisher to be dissolved. Therefore, in this Example, cleaning of the glass substrate was performed using the cleaning solution composed of sulfuric acid, L-ascorbic acid, and hydrofluoric acid.

The glass substrate which has been subjected to the end face mirror polishing process was immersed in the cleaning solution having the above composition containing sulfuric acid, L-ascorbic acid, and hydrofluoric acid, thereby carrying out the cleaning treatment. The glass substrate was immersed in this cleaning solution for about 5 minutes. The temperature of the cleaning solution was set to about 40°C.

The surface roughness of a 5μm-long and 5μm-broad square region of the end face of the glass substrate which has been subjected to the cleaning treatment was measured by an atomic force microscope (AFM) to be 4.0nm in Rmax, 2.0nm in Rp, 2.0nm in Rv, and 0.4nm in Ra. Further, using the atomic force microscope and an electron microscope, the surface thereof was analyzed. As a result, the surface had a mirror surface state and no convex or concave defect or foreign matter was observed. Residue of the polisher was also not detected.

[0042]

(4) Lapping Process

Then, a lapping treatment was applied to the glass substrate. This lapping process is intended to improve the dimensional accuracy and the shape

accuracy. The lapping treatment was performed using a lapping machine and carried out twice by changing the grain size of abrasive grains to #400 and #1000. Specifically, at first, using alumina abrasive grains of grain size #400 and rotating a sun gear and an internal gear, the main surfaces on both sides of the glass substrate placed in a carrier were lapped to a profile irregularity of 0 to $1\mu\text{m}$ and a surface roughness (R_{max}) of about $6\mu\text{m}$. Then, after the grain size of the alumina abrasive grains was changed to #1000, lapping was carried out, thereby obtaining a surface roughness (R_{max}) of about $2\mu\text{m}$. The glass substrate which has been subjected to the lapping treatment was immersed successively in respective cleaning baths of neutral detergent and water to be subjected to cleaning.

[0043]

(5) First Polishing Process

Then, the first polishing process was carried out. This first polishing process is intended to remove cracks and distortion remaining in the foregoing lapping process and was carried out using a polishing machine. Specifically, using polyurethane hard polishing pads, the first polishing process was performed under the following polishing condition. As a polisher, a cerium oxide polisher was used. The glass substrate which has been subjected to the above first polishing process was immersed successively in respective cleaning baths of neutral detergent, pure water, pure water, IPA (isopropyl alcohol), and IPA (steam drying) to be subjected to cleaning.

(6) Second Polishing Process (Main Surface Mirror Polishing Process)

Then, the second polishing process was carried out using a polishing machine same as that used in the first polishing process, while the hard polishing pads were changed to soft polishing pads. A treatment performed in this second polishing process is a mirror polishing treatment in which, while maintaining the flat main surfaces obtained in the foregoing first polishing

process, the main surfaces were finished to smooth mirror surfaces, for example, having a surface roughness R_{max} of about 6nm or less. As the polishing pads, use was made of soft magnetic pads having an Asker C hardness of 72. Further, the surface of each polishing pad was made of polyurethane foam formed with foam pores. As a polishing solution, use was made of a polishing solution in which a cerium oxide polisher was dispersed in pure water. The average grain size of the polisher was 0.8 μ m. By supplying this polishing solution to the glass substrate and slidably moving the polishing pads and the glass substrate to each other, the surfaces of the glass substrate were mirror-polished.

The glass substrate which has been subjected to the above second polishing process was immersed successively in respective cleaning baths of neutral detergent, pure water, pure water, IPA (isopropyl alcohol), and IPA (steam drying) to be subjected to cleaning.

[0044]

(7) Chemical Strengthening Process

A chemical strengthening treatment was applied to the glass substrate which has been subjected to the second polishing process. The chemical strengthening treatment is performed by putting a chemical strengthening salt into a chemical strengthening treatment vessel and immersing the glass substrate retained by a retaining member in the molten chemical strengthening salt. In a specific method of the chemical strengthening treatment, a chemical strengthening salt in the form of a mixture of potassium nitrate and sodium nitrate was prepared. This chemical strengthening salt was heated to 400°C to be melted. The cleaned glass substrate preheated to 300°C was immersed therein for about 3 hours. In this manner, by immersing the glass substrate in the molten chemical strengthening salt, lithium and sodium in surface layers of the glass substrate are replaced by sodium and potassium in the molten

chemical strengthening salt, respectively, so that the glass substrate is chemically strengthened. The thickness of each of compressive stress layers formed at the surface layers of the glass substrate was about 100 μ m. The glass substrate finished with the chemical strengthening treatment was subjected to cleaning and drying processes in the order of sulfuric acid cleaning, neutral detergent cleaning, pure water cleaning, alcohol cleaning, and alcohol steam drying.

Using the atomic force microscope and the electron microscope, the main surfaces of the glass substrate obtained through the foregoing processes were analyzed. As a result, the surfaces had a mirror surface state and no convex or concave defect or foreign matter was observed. Residue of the polisher was also not detected.

In the manner as described above, the glass substrate for the magnetic disk was manufactured.

[0045]

(8) Magnetic Disk Manufacturing Process

On each of both surfaces of the glass substrate for the magnetic disk obtained through the foregoing processes, a first underlayer of NiTa, a second underlayer of Ru, and a CoCrPtB magnetic layer were successively formed using a DC magnetron sputtering apparatus. Then, a hydrogenated carbon protective layer was formed to a thickness of 40 angstroms by a plasma CVD method. A film of an alcohol-denatured perfluoropolyether lubricant was formed by coating to a thickness of 10 angstroms by a dipping method, thereby manufacturing a magnetic disk. This magnetic disk is a magnetic disk of the perpendicular magnetic recording type.

[0046]

[HDD Mounting Test]

The obtained magnetic disk was mounted in a load/unload type hard

disk drive (HDD) having a maximum recording density of 60 gigabits per inch². The flying height of a magnetic head mounted in this hard disk drive is 10nm and, as a slider, an NPAB slider (negative pressure slider) is employed. A reproducing element is a magnetoresistive effect reproducing element. A test was performed using this hard disk drive. As a result, it was possible to safely carry out recording/reproduction with no occurrence of head crash failure, thermal asperity failure, or fly stiction failure. Load/unload operations were repeated 600,000 times, but no failure occurred.

[0047]

[Example 2][Comparative Example 1]

Various cleaning solutions were composed as cleaning solutions in the cleaning process (cleaning process after end face mirror polishing) and their cleaning abilities were compared with each other. Compositions of the cleaning solutions, actions of the cleaning solutions, and effects of the cleaning solutions are collectively shown in Table 1 below. Other than these points, glass substrates for magnetic disks and magnetic disks are manufactured by the manufacturing method same as that in Example 1 and are same as those in Example 1. Evaluation methods and so on are as described above.

[0048]

	Composition of Cleaning Solution			Action on Polisher	Action on Glass		Glass End Face after Cleaning			HDD Mounting Test
	Sulfuric Acid Concentration [wt%]	Ascorbic Acid Concentration [wt%]	Hydro-fluoric Acid Addition Amount Concentration [ppm]		Leach-ability to Glass	Etch-ability to Glass	Maximum Valley Depth Rv[nm]	Maximum Peak Height Rp[nm]	Maximum Roughness Rmax[nm]	
Example 1	4.5	1	10	yes	no	no	2	2	4	mirror surface no failure
Example 2-1	3	1	10	yes	no	no	same as Example 1			mirror surface no failure
Example 2-2	10	1	10	yes	no	no				mirror surface no failure
Example 2-3	4	0.1	8	yes	no	no				mirror surface no failure
Example 2-4	4	3	8	yes	no	no				mirror surface no failure
Example 2-5	5	2	1	yes	no	no				mirror surface no failure
Example 2-6	5	2	30	yes	no	no				mirror surface no failure
Comparative Example 1-1	1.5	1	10	yes	yes	no	6	2	8	with depression with fly stiction
Comparative Example 1-2	4.5	0	0	no	no	no	2	8	10	with thermal asperity

Table 1

[0049]

[Comparative Example 2]

Next, in the foregoing end face mirror polishing process, mirror polishing was carried out using a cerium oxide polisher containing fluorine in an amount of 6wt% in terms of F (fluorine atoms). Other than this point, a glass substrate for a magnetic disk and a magnetic disk are manufactured by the manufacturing method same as that in Example 1 and are same as those in Example 1. Evaluation methods and so on are as described above.

As a result, solubility to the polisher was not sufficient and, when the surface of the glass substrate after cleaning was observed by the atomic force microscope and the electron microscope, fine projections supposed to be residue of the polisher were confirmed. Further, there were found some portions where depressions were formed and some portions where the surface roughness was large. It is supposed that residue of the polisher exerted an etching action in fine regions of the glass substrate.

Likewise, experiments were performed using fluorine-containing cerium oxide polishers with various F (fluorine atoms) contents (5wt%, 2wt%, 1wt%) and it was found out that the same results as those in Example 1 were obtained in the case of 5wt% or less.

[0050]

[Reference Example]

Next, description will additionally be made of reference experiments according to the embodiment of this invention.

Preparation was made of reagents having compositions similar to that of the cleaning solution used in the cleaning process (cleaning process after end face mirror polishing) of Example 1 and actions on an aluminosilicate glass were examined. Specifically, the composition about sulfuric acid and ascorbic acid was same as that of the cleaning solution in Example 1, while the addition

amount of hydrofluoric acid was adjusted. Thus, reagents having various fluorine ion concentrations were prepared. Normally, hydrofluoric acid is a liquid that is used as an etching solution for a glass. Therefore, it is better to disclose, herein, the fluorine ion concentration that does not inhibit the function/effect of this invention.

[0051]

Specifically, preparation was made of reagents with seven levels of fluorine ion concentrations, i.e. 1ppm, 5ppm, 10ppm, 30ppm, 40ppm, 50ppm, and 100ppm. By bringing these reagents into contact with an aluminosilicate glass having the same composition as that in Example 1, the etching rates were examined. As a result, it was found out that, when the fluorine ion concentration was 40ppm or less, the etching rate was 0.01nm/min at most and thus the etching action did not substantially occur. On the other hand, the etching rate rapidly increased to 0.1nm/min at 50ppm and exceeded 0.5nm/min at 100ppm. By precisely managing the time for carrying out the cleaning treatment, it is possible to control the etching amount to be a predetermined value or less even at 50ppm or more. However, the process management becomes difficult. Therefore, in view of maintaining the stable mass-production processes, it is preferable to set the fluorine ion concentration to 40ppm or less.

[0052]

[Example 3]

Next, a glass substrate for a magnetic disk and a magnetic disk were manufactured which have been subjected to a tape polishing treatment between the chemical strengthening process and the magnetic disk manufacturing process in Example 1. By applying the tape polishing treatment to each of the surfaces of the disk-shaped glass substrate, a texture comprising stripe-shaped grooves oriented in the circumferential direction of the disk was formed. Specifically, by abutting a polishing tape in the form of a cloth of resin fibers

against the surface of the glass substrate having been subjected to the chemical strengthening treatment and rotating the glass substrate while supplying diamond abrasive grains, a fine texture was formed on the surface of the glass substrate. The surface of the glass substrate which has been subjected to this texture forming treatment was observed by the atomic force microscope. Then, the surface roughness was equal to that in Example 1, but the fine texture shape was formed on the surface. The stripes forming the texture were oriented along the circumferential direction of the disk. A convex portion, a concave portion, a crack formed by biting of foreign matter, or the like that would otherwise disturb the texture shape were not observed. The same film formation as in Example 1 was performed on the glass substrate, thereby manufacturing a magnetic disk. However, the first underlayer was changed to a CrTa underlayer, the second underlayer was changed to an AlRu underlayer, and a CrMo underlayer was interposed as a third underlayer between the second underlayer and the magnetic layer.

[0053]

In the manner as described above, the magnetic disk of the in-plane recording type was manufactured. Other than these points, the glass substrate for the magnetic disk and the magnetic disk are manufactured by the manufacturing method same as that in Example 1 and are the same as those in Example 1.

An HDD mounting test was performed for the obtained magnetic disk and preferable results like those in Example 1 were obtained. Then, the magnetic anisotropy of the magnetic disk was examined. Specifically, a coercive force (H_{c1}) in the circumferential direction of the magnetic disk and a coercive force (H_{c2}) in the radial direction thereof were measured and H_{c1}/H_{c2} was evaluated as a magnetic anisotropy index (OR). A magnetic property evaluation method by a VSM (vibrating sample magnetometer) was employed

for the measurement of the coercive force. In this event, the maximum applied external magnetic field was set to 8 kilo-oersteds. As a result, OR was about 1.2. This represents that, in this magnetic disk, the magnetic property (coercive force in this case) in the circumferential direction is better than that in the radial direction by 20%.

CLAIMS

1. A method of manufacturing a glass substrate for a magnetic disk, which includes mirror polishing and cleaning processes of a glass substrate, said method further comprising:

supplying to the glass substrate a polisher mainly containing a rare earth oxide and having a fluorine content of 5wt% or less, mirror-polishing an end face of the glass substrate by relatively moving a polishing cloth and the glass substrate to each other, and then bringing the glass substrate into contact with a cleaning solution containing ascorbic acid, fluorine ions, and 3wt% or more sulfuric acid to thereby dissolve and remove said polisher.

2. The method according to claim 1, wherein a concentration of the ascorbic acid contained in said cleaning solution is set to 0.1wt% or more.

3. The method according to claim 1 or 2, wherein a content of the fluorine ions contained in said cleaning solution is set to 1ppm or more and 40ppm or less.

4. The method according to any one of claims 1 to 3, wherein a glass forming said glass substrate is an amorphous aluminosilicate glass mainly containing 58wt% or more and 75wt% or less SiO_2 , 5wt% or more and 23wt% or less Al_2O_3 , 3wt% or more and 10wt% or less Li_2O , and 4wt% or more and 13wt% or less Na_2O .

5. The method according to any one of claims 1 to 4, wherein said end face of the glass substrate after said cleaning process is a mirror surface having a maximum valley depth R_v of 4nm or less.

6. A method of manufacturing a magnetic disk, the method comprising forming at least a magnetic layer on the glass substrate manufactured by the method according to any one of claims 1 to 5.

7. The method according to claim 6, wherein the magnetic disk

adapted to record/reproduce information is manufactured at a bit recording density of 60 gigabits per inch² or more.