

## DESCRIPTION

### METHOD OF MANUFACTURING A GLASS SUBSTRATE FOR A MAGNETIC DISK

This application is based upon and claims the benefit of priority from Japanese patent application No. 2008-048086, filed on February 28, 2008, the disclosure of which is incorporated herein in its entirety by reference.

#### Background of the Invention:

This invention relates to a method of manufacturing a glass substrate for a magnetic disk.

In recent years, the information recording technique, particularly the magnetic recording technique, has remarkably advanced following the development of information technology. With the reduction in size and thickness and the increase in recording density of magnetic disks, glass substrates excellent in substrate main surface flatness and substrate strength have started to be used as substrates for magnetic recording media such as HDDs (hard disk drives) being one of the magnetic recording media, instead of aluminum substrates that have conventionally been widely used.

Magnetic disks have been required to be increased in recording density and, in recent years, the increase in information recording density of magnetic disks has been achieved up to about 200Gbit/inch<sup>2</sup>. Following this increase in recording density, magnetic heads have also shifted from thin film heads to magnetoresistive heads (MR heads) and giant magnetoresistive heads (GMR heads), wherein the flying height of a magnetic head from a substrate (magnetic disk) has been reduced to about 20nm to 5nm. By reducing the

flying height (magnetic spacing) of the magnetic head from the magnetic disk in this manner, it has been possible to improve the spacing loss to increase the S/N ratio (signal/noise ratio) and thus to achieve a further increase in recording density.

Such a magnetoresistive head (MR head) or giant magnetoresistive head (GMR head) controls the flying height by the pressure of air between the relatively moving magnetic head and magnetic disk. That is, the flying height of the magnetic head from the magnetic disk is determined by a balance between a positive pressure (a pressure exerted in a direction in which the magnetic head flies from the magnetic disk) and a negative pressure (a pressure in a direction in which the magnetic head is adsorbed to the magnetic disk, generated by increasing the volume of air and thus reducing the pressure in a space intentionally provided at the bottom surface of a slider of the magnetic head) generated by an air flow.

As one of techniques for stabilizing the control of the magnetic head flying height described above and achieving a further reduction in flying height, the technique called DFH (Dynamic Flying Height) has been developed in recent years. Specifically, a heater element is embedded in a magnetic head and, during operation of the magnetic head, the heater element is heated. The magnetic head is thermally expanded by its heat and slightly projected toward a magnetic disk. By this, the magnetic spacing being a magnetic gap between the magnetic head and the main surface of the magnetic disk can be reduced only in that event (during operation of the magnetic head). That is, DFH is a technique that can reduce the flying height of a magnetic head from a magnetic disk.

With such a DFH head, a further reduction in flying height has been achieved. However, a magnetic head is mounted with an MR element

(magnetoresistive element) and there is a problem that it causes, as its inherent failure, the head crash failure or thermal asperity failure. Since these failures occur due to minute irregularities on the surface of a magnetic disk, the main surface of the magnetic disk is required to have extremely high-level smoothness and flatness.

As means for evaluating such flying characteristics affected by the smoothness of a magnetic disk, there is, for example, an inspection by a glide test. The glide test is a method of disposing a glide head (a head equipped with an impact detecting sensor such as a PZT (piezoelectric element)) so as to face the main surface of a magnetic disk and evaluating the flying characteristics by relatively moving the glide head with respect to the magnetic disk at a predetermined glide height.

As described above, even glass substrates excellent in flatness as compared with aluminum substrates have been required to have further smoothness and flatness. Herein, similar to or more than smoothly and flatly polishing the glass substrates, particles such as dust that adhere to the main surfaces of the glass substrates become a problem. This is because if a magnetic layer is formed on a glass substrate contaminated with particles, convex defects occur on a magnetic disk to cause the head crash failure or thermal asperity failure. Therefore, the operation of forming magnetic layers/protective layers etc. on the main surfaces of the glass substrates is normally carried out in a clean room.

Herein, there arises a problem of particles that adhere to the glass substrates while transporting the glass substrates to a magnetic disk production site from the manufacture of the glass substrates. Generally, in a magnetic disk production process, the glass substrates are first cleaned to thereby remove adhering particles. However, it is not possible to remove any amounts

of particles. If there is a difference in amount of particles adhering to the glass substrates, there also occurs a difference in amount of particles remaining on the glass substrates after the cleaning. Therefore, it is necessary to reduce as much as possible the particles adhering to the glass substrates at the time of transfer-in (after unpackaging) and, for this, a packaging method, an unpackaging method, a packaging structure, and a packaging material comprised in a glass substrate or magnetic disk manufacturing method are extremely important.

As a related art handling magnetic disks, not glass substrates, as packaging objects, there is a technique wherein magnetic disks are transported while being placed in a receiving container and double packaged with a first packaging bag and a second packaging bag as described in, for example, Japanese Unexamined Patent Application Publication (JP-A) No. H11-157591 (Patent Document 1). According to this package, since the magnetic disks are sealed in the packaging bags, it is possible to prevent invasion of particles or foreign matter into the packaging bags.

#### Disclosure of the Invention:

The packaging technique for preventing contamination of the magnetic disks has been proposed by Patent Document 1. However, even if such packaging technique is applied to packaging of the glass substrates, this does not achieve sufficient reduction in amount of particles adhering to the glass substrates after unpackaging. Therefore, it is not possible to satisfy the smoothness/flatness standard required for the magnetic disks following recent development for higher recording density of the magnetic disks and lower flying height of the magnetic heads. It is therefore necessary to further reduce the amount of particles adhering to the glass substrates.

In view of the subject described above, it is an object of this invention to provide a method of manufacturing a glass substrate for a magnetic-disk capable of improving the magnetic disk yield rate by more reliably preventing adhesion of dust or foreign matter to a glass substrate.

As a result of diligent studies on the above subject, the inventors of this application have discovered that when packaging a case in which a glass substrate is placed, particles are present in a packaging bag thereof and the case, have found that preventing adhesion of such particles to the glass substrate is effective for improving the glass substrate yield rate and thus improving the magnetic disk yield rate, and have come to complete this invention.

In order to solve the above subject, a typical structure of a method of manufacturing a glass substrate for a magnetic-disk according to this invention, comprising; placing one or more glass substrates for magnetic-disks in a case, placing the case in a packaging bag, degassing the inside of the packaging bag by performing decompression at a decompression rate of 0.1MPa/sec or less, and sealing the packaging bag by hermetically closing an opening portion of the packaging bag in a degassed state.

According to the above configuration, by slowly degassing the inside of the packaging bag at a decompression rate of 0.1MPa/sec or less, it is possible to reduce the occurrence of an air flow in the case and the packaging bag and thus to remove particles present in the packaging bag and the case without adhering to the glass substrate. Therefore, during the degassing, it becomes possible to prevent particles present in the case and the packaging bag from being moved by an airflow and thus to prevent such particles from impinging on and adhering to main surfaces of the glass substrate.

If degassed and sucked rapidly, there is a possibility that particles in an

atmosphere vigorously adhere to the main surfaces of the glass substrate and thus are fixed thereto so firmly that the particles cannot be removed by cleaning. However, according to the above configuration, particles can be sucked while being carried on an airflow, so as to be removed to the outside of the packaging bag. Even if the particles are brought into contact with the main surfaces of the glass substrate, the kinetic energy of the particles is so small because of the degassing being slow that the particles have difficulty in adhering thereto and that even if the particles adhere thereto, those can be easily removed by cleaning.

Further, by sealing the packaging bag by hermetically closing the opening portion of the packaging bag in the degassed state, it is possible to remove air containing particles and water vapor in the packaging bag to thereby obtain a state close to vacuum and further to prevent invasion of particles and water vapor from the outside of the packaging bag. By removing water vapor in the packaging bag, it is possible to prevent such water vapor from liquefying due to the difference in temperature during transfer and adhering to the glass substrates and thus to avoid a change in the state of the main surfaces of the glass substrate. Therefore, it is possible to maintain the state of the glass substrate to be good from shipping of the glass substrate after packaging thereof until unpackaging thereof after transfer thereof.

The above packaging bag is preferably made of a metal laminate film.

Since the metal laminate film has high shielding property against water vapor or gas, the state degassed and sealed at the time of packaging can be maintained over a long period of time. As a metal of the metal laminate, use can be suitably made of aluminum, a stainless material, chromium, a steel plate subjected to chromic-acid treatment, phosphoric-acid treatment, chromate treatment, or plating with nickel, tin, or zinc, or the like. As materials for

laminating the above metal, there can be cited a polyethylene film, an aluminum film, a drawn nylon (polyamide) film, a polyethylene terephthalate film, and so on. By laminating these materials, the water vapor permeability and the oxygen permeability of the packaging bag can be reduced.

It is preferable that the above hermetic closing be in a heat sealing manner of linear bonding under heat and pressure and comprise performing first hermetic closing and then further performing second hermetic closing inside a position of the first hermetic closing.

By carrying out the hermetic closing with double heat sealings as described above, it is possible to increase the heat seal strength. There is a possibility that the heat sealing hermetically closed by manual operation is weaker than the other sides industrially processed. However, with the double sealings, even if the inner (second) heat sealing should come to fail due to the difference in atmospheric pressure, the inside of the packaging bag can be maintained in the sealed state by the outer (first) heat sealing.

If the above heat sealings are performed in order of first on the inside and second on the outside, air remains between both heat sealings. Therefore, in the invention of this application, by performing the heat sealings in order of first on the outside and second on the inside, a region between both heat sealings is maintained in a state close to vacuum and, therefore, even if the inner heat sealing comes to fail, the incorporation of air into the packaging bag does not occur.

It is preferable to further place in a second packaging bag the packaging bag sealed with the case placed therein, to degas the inside of the second packaging bag by decompression, and to seal the second packaging bag by hermetically closing an opening portion of the second packaging bag.

According to the above configuration, since both the packaging bag

and the second packaging bag are degassed and sealed, permeation of water vapor or gas can be prevented more effectively so that the sealed state can be maintained over a long period of time. Further, by double packaging the case, even if the second packaging bag is perforated due to collision or the like during transfer, the inside packaging bag can be maintained in the sealed state. Hereinbelow, the inside packaging bag described earlier will be called a "first packaging bag".

The subject glass substrate for a magnetic disk is preferably used for manufacturing a magnetic disk that is recorded using a DFH head.

Since the glass substrate for a magnetic disk manufactured by the manufacturing method according to this invention has a reduced amount of particles as compared with a glass substrate for a magnetic disk manufactured by a conventional manufacturing method, the cleanness of the main surfaces of the glass substrate is high. Therefore, the glass substrate for a magnetic disk according to this invention is suitably used for a magnetic disk that is recorded in a magnetic recording system using a DFH head with a low flying height.

The subject glass substrate for a magnetic disk is preferably used for manufacturing a magnetic disk over which the flying height of a magnetic head is 10nm or less in recording on the magnetic disk.

As described above, the cleanness of the main surfaces of the glass substrate for a magnetic disk manufactured by the method of manufacturing according to this invention is high as compared with that of the glass substrate for a magnetic disk manufactured by the conventional manufacturing method. Therefore, a magnetic disk manufactured using such a glass substrate has high smoothness and flatness and thus can be adapted to a recording system in which the flying height of a magnetic head is 10nm or less.

The subject glass substrate for a magnetic disk is preferably used for

manufacturing a magnetic disk with a recording density of 200Gbit/inch<sup>2</sup> or more.

As described above, the smoothness and flatness of the main surfaces of the glass substrate for a magnetic disk manufactured by the manufacturing method according to this invention are high as compared with those of the glass substrate for a magnetic disk manufactured by the conventional manufacturing method. Therefore, a magnetic disk manufactured using such a glass substrate can be suitably applied to a magnetic disk with a recording density of 200Gbit/inch<sup>2</sup> or more whose high recording density is achieved by a recording system in which the flying height of a magnetic head is low.

According to this invention, it is possible to provide a method of manufacturing a glass substrate for a magnetic-disk capable of improving the magnetic disk yield rate by more reliably preventing adhesion of dust or foreign matter, present in a packaging bag and a case, to a glass substrate.

#### Brief Description of the Drawings:

Fig. 1 shows diagrams for explaining a glass substrate for a magnetic disk 100 according to this invention.

Fig. 2 shows diagrams for explaining a state where glass substrates 100 are placed in a case 200.

Fig. 3 shows diagrams for explaining a state where cases 200 with glass substrates 100 placed therein are packaged with a first packaging bag 210.

Fig. 4 shows diagrams for explaining details of the first packaging bag 210.

Fig. 5 shows a diagram for explaining a state where the cases 200 with the glass substrates 100 placed therein are packaged with a second packaging

bag 220.

Fig. 6 shows graphs each illustrating the relationship between the decompression rate and the number of particles.

#### Preferred Embodiment for Carrying Out the Invention:

First, a glass substrate for a magnetic disk according to this embodiment will be described. Fig. 1 shows diagrams for explaining a glass substrate for a magnetic disk 100 according to this embodiment, wherein Fig. 1(a) is a perspective view of the glass substrate for a magnetic disk 100. The glass substrate for a magnetic disk 100 has a disk shape with an inner hole formed at the center thereof. Each of main surfaces 110 is a region for recording/reproducing information and thus is substantially smooth for allowing a recording head to fly thereover.

Fig. 1(b) is an X-X sectional view of Fig. 1(a). The glass substrate for a magnetic-disk 100 comprises the main surfaces 110 that will serve as information recording/reproducing regions, an end face 120 perpendicular to the main surfaces 110, and chamfered faces 130 interposed between the main surfaces 110 and the end face 120, respectively. Since it may happen that the boundary between the end face 120 and each chamfered face 130 becomes unclear by a later-described end face polishing process, this embodiment also comprises a case where the end face 120 and the chamfered faces 130 on both sides thereof cooperatively form one curved surface.

If particles or foreign matter adheres to the glass substrate for a magnetic disk 100, particularly to the main surfaces 110 thereof, before a magnetic-disk film forming process, smooth magnetic layers cannot be formed on the glass substrate 100 in the film forming process and thus the yield rate of magnetic disks as final products decreases.

Fig. 2 shows diagrams for explaining a state where glass substrates for a magnetic-disks 100 are placed in a case 200, wherein Fig. 2(a) is an enlarged view of the generally rectangular parallelepiped plastic glass-substrate case 200 serving as a container for storing the glass substrates for a magnetic-disks 100. The case 200 is capable of accommodating 25 glass substrates and the glass substrates for magnetic disks 100 are stored in the case 200. A plurality of (four in this embodiment) cases 200 with the glass substrates for a magnetic-disks 100 placed therein are arranged side by side as shown in Fig. 2(b) and are, in this state, put in a later-described first packaging bag 210. The number of glass substrates for magnetic disks 100 placed in the case 200 may be one or more and is not particularly limited.

Fig. 3 shows diagrams for explaining a state where the cases 200 with the glass substrates for magnetic disks 100 placed therein are packaged with the first packaging bag 210. The plurality of cases 200 with the glass substrates for a magnetic-disks 100 placed therein are, in the state of being arranged side by side as shown in Fig. 2(b), first put in the first packaging bag 210 made of a metal laminate film as shown in Fig. 3(a). Thereafter, two pipes 202 connected to a decompressor (not illustrated) are inserted into an opening portion of the first packaging bag 210, thereby decompressing and degassing the inside of the first packaging bag 210.

In this event, the rate of degassing the inside of the first packaging bag 210 is preferably a decompression rate of 0.1MPa/sec or less. By degassing at such a decompression rate, it is possible to prevent airflow from being generated in air in the cases 200 and the packaging bag (first packaging bag 210) during the degassing. This makes it possible to prevent particles present in the cases 200 and the packaging bag (first packaging bag 210) from being moved by such airflow to impinge on and adhere to the main surfaces 110 of

the glass substrates for magnetic disks 100. Further, even if the particles are brought into contact with the main surfaces 110 of the glass substrates for a magnetic-disks 100, the kinetic energy of the particles is so small at the above decompression rate that the particles have difficulty in adhering thereto and that even if the particles adhere thereto, those can be easily removed by cleaning.

Thereafter, in the state where the inside of the first packaging bag 210 is degassed as described above, the opening portion of the first packaging bag 210 is linearly bonded under heat and pressure in a heat sealing manner so as to be hermetically closed, thereby sealing the first packaging bag 210. Such hermetic closing comprises, as shown in Fig. 3(b), first carrying out first heat sealing 214a near the opening of the first packaging bag 210 and then carrying out second heat sealing 214b inside the heat sealing 214a. By the hermetic closing with the double heat sealings in this manner, it is possible to increase the heat seal strength. In this event, the heat seal strength is 24.5N/15mm.

Further, by performing the heat sealings in order of first on the outside and second on the inside as described above, a region between both heat sealings is maintained in a state close to vacuum and, therefore, even if the inner heat sealing comes to fail, the incorporation of air into the packaging bag (first packaging bag 210) does not occur. If this heat sealing order is reversed, air remains between both heat sealings.

Further, in the case of the above double heat sealings, the inside of the first packaging bag 210 can be maintained in the sealed state over a long period of time as compared with a case where hermetic closing is performed by only one-time heat sealing. Further, even if the inner (second) heat sealing should come to fail due to the difference in atmospheric pressure, the inside of the packaging bag (first packaging bag 210) can be maintained in the sealed

state by the outer (first) heat sealing. With the above configuration, it is possible to prevent invasion of particles and water vapor from the outside into the packaging bag (first packaging bag 210) and thus to maintain the state of the glass substrates for a magnetic-disks 100 to be good from shipping of the glass substrates for a magnetic-disks 100 after packaging thereof until unpackaging thereof after transfer thereof.

As described above, the cases 200 are packaged with the first packaging bag 210 in the form of the metal laminate film so as to be sealed in the degassed state, thereby forming a package 212. By packaging the cases 200 according to such a method, particles present in the cases 200 and the packaging bag (first packaging bag 210) can be removed by the degassing and therefore it is possible to prevent adhesion of the particles to the glass substrates for a magnetic-disks 100 and thus to avoid contamination of the main surfaces 110 of the glass substrates for a magnetic-disks 100. Further, by the degassing, water vapor contained in air in the cases 200 and the packaging bag (first packaging bag 210) is removed. Therefore, it is possible to prevent such water vapor from liquefying due to the difference in temperature during transfer and adhering to the glass substrates for a magnetic-disks 100 and thus to prevent a change in the state of the main surfaces 110 of the glass substrates for a magnetic-disks 100.

Fig. 4 shows diagrams for explaining details of the first packaging bag 210, wherein Fig. 4(a) is a diagram showing one example of the size of the first packaging bag 210. The first packaging bag 210 is heat-sealed at a hatched portion 216 so as to be formed into a bag shape. Thereafter, as described above, the first packaging bag 210 is, after the cases 200 are put therein, degassed inside and then hermetically closed by double heat-sealing an opening portion 218.

The longitudinal and transverse size of the first packaging bag 210 is set to 500mm×400mm and the width of the heat-sealed portion 216 is set to 10mm, but these numerical values are only illustrative. As shown in the same figure, four corners of the first packaging bag 210 are each rounded into a curved shape with a radius of curvature of 1mm. Alternatively, the corners each may have an obtuse angle.

The metal laminate film used as the first packaging bag 210 has high hardness and, if heat-sealed by bonding under heat and pressure, it further loses its flexibility to increase its hardness. On the other hand, a second packaging bag 220 (details will be described later) serving as an outer bag uses a plastic film and therefore it has high flexibility and thus cannot obtain so much strength. Accordingly, if the second packaging bag 220 directly packages the first packaging bag 210 so that both are in tight contact with each other, there is a possibility that the outside second packaging bag 220 is torn due to the pointed shape of four corners of the inside strong first packaging bag 210. Particularly, it is fully expected that the corners of the first packaging bag 210 repeatedly contact the same portions of the second packaging bag 220 due to vibration or external pressure during transfer. Therefore, by chamfering (rounding or making obtuse) the four corners of the first packaging bag 210, tearing of the second packaging bag 220 is effectively prevented.

Experimentally, the chamfering of the corners of the first packaging bag 210 is satisfactory if, although depending on the strength of the second packaging bag 220, the radius of curvature is about 1/10 of the width of a portion to be heat-sealed. The reason for setting the radius of curvature to 1mm in this embodiment is that this value represents a radius of curvature being about 1/10 of the width of the heat-sealed portion 216 and thus is sufficient for ensuring the tearing preventing function.

Fig. 4(b) is a schematic diagram showing a laminate structure of the first packaging bag 210. In this embodiment, as described above, the first packaging bag 210 is made of the metal laminate film. In this application, if a film is composed of a plurality of stacked films and at least one of them is a film made of a metal, the film is called a metal laminate film. As such a metal, use can be suitably made of aluminum, a stainless material, chromium, a steel plate subjected to chromic-acid treatment, phosphoric-acid treatment, chromate treatment, or plating with nickel, tin, or zinc, or the like.

The specific structure of the metal laminate film is as shown in Fig. 4(b). That is, the first packaging bag 210 comprises, from the inside, a polyethylene film 410, an aluminum film (metal film) 420, a drawn nylon (polyamide) film 430, and a polyethylene terephthalate film 440 that are stacked together. By laminating these materials in the above order, the water vapor permeability and the oxygen permeability can be reduced.

The above water vapor permeability of the first packaging bag 210 is preferably  $0.1\text{g/m}^2 \cdot \text{day}$  or less. By this, it is possible to prevent the glass substrates for a magnetic disks 100 from being exposed to moisture and contaminated and thus to prevent a change in the state of the main surfaces 110. On the other hand, the oxygen permeability of the first packaging bag 210 is preferably  $0.1\text{cc (ml)/m}^2 \cdot \text{day}$  or less. By this, as in the case where the water vapor permeability is low, it is possible to prevent a change in the state of the main surfaces 110 of the glass substrates for magnetic disks 100.

As described above, by packaging the glass substrates for a magnetic-disks 100 with the metal laminate film whose water vapor permeability and oxygen permeability take the above values, the shielding property against water vapor or gas is enhanced to enable the degassed and sealed state to be maintained over a long period of time and thus it is possible

to reliably avoid a change in the state of the main surfaces 110 otherwise caused by a chemical change due to exposure of the glass substrates for a magnetic-disks 100 to moisture.

Fig. 5 is a diagram for explaining a state where the cases 200 with the glass substrates for magnetic disks 100 placed therein are packaged with the second packaging bag 220. As shown in Fig. 5, the cases 200 packaged with the first packaging bag 210 (package 212) are further placed in the second packaging bag 220 made of the plastic film. Thereafter, in the state where the inside of the second packaging bag 220 is decompressed and degassed, the second packaging bag 220 is hermetically closed by heat sealing 224 in the form of linear bonding under heat and pressure so as to be sealed, thereby forming a double package 222. This plastic film may be, for example, polyethylene. Although the plurality of cases 200 are packaged in the state of being stacked in this embodiment, packaging may be carried out per case 200.

According to the above configuration, since both the first packaging bag 210 and the second packaging bag 220 are degassed inside and sealed, permeation of water vapor or gas is effectively prevented so that the sealed state can be maintained over a long period of time. Such degassing may be carried out after filling an inert gas such as nitrogen. Further, by double packaging the cases 200, even if the second packaging bag 220 is perforated due to collision or the like during transfer, the inside packaging bag (first packaging bag 210) can be maintained in the sealed state.

Further, according to the above configuration, it is possible to prevent adhesion of particles to the glass substrates for magnetic disks 100 when unpackaging the first packaging bag 210 and the second packaging bag 220 in a magnetic disk manufacturing plant after transfer of the glass substrates for magnetic disks 100. After the transfer, the outside second packaging bag 220

with particles adhering thereto is first unpackaged. Then, in a room different from a room where the second packaging bag 220 is unpackaged, the inside first packaging bag 210 is unpackaged and then the glass substrates for a magnetic-disks 100 placed in the cases are transferred into a clean room.

Accordingly, when the second packaging bag 220 is unpackaged, it is possible to almost completely remove the particles that adhere during transportation, and therefore, it is possible to prevent adhesion of the particles to the glass substrates for a magnetic-disks 100 just before transfer thereof into the clean room where formation of magnetic layers and so on is carried out.

In this embodiment, the plastic film is used as the second packaging bag 220. However, it is also considered to use the metal laminate film for both the first packaging bag 210 and the second packaging bag 220. However, the metal laminate film has a complicated structure as compared with a plastic film such as a polyethylene film and thus the material cost is also high. Therefore, by shielding water vapor or gas with the first packaging bag 210 made of the metal laminate film and preventing invasion of dust (particles) and most of water vapor with the second packaging bag 220 made of the plastic film, it is possible to suppress the material cost to be low while ensuring the packaging performance.

Hereinabove, the description has been made of the embodiment of the glass substrate for a magnetic-disk manufacturing method according to this invention. Since the subject glass substrate for a magnetic disk has a reduced amount of particles as compared with a glass substrate for a magnetic disk manufactured by a conventional manufacturing method, the smoothness and flatness of the main surfaces of the glass substrate for a magnetic disk are high. Therefore, it can be used for a magnetic disk that is recorded in a recording system using a magnetic head with a low flying height, i.e. a recording system

in which the flying height of a magnetic head is 10nm or less, and thus is required to have high smoothness and flatness. Further, from the same point of view, the subject glass substrate for a magnetic-disk is also suitably used for a magnetic disk that is recorded in a magnetic recording system using a DFH head with a low flying height and, further, it can also be used for a magnetic disk with a recording density of 200Gbit/inch<sup>2</sup> or more whose high recording density has been achieved by a reduction in flying height of a magnetic head.

In addition, the smoothness of a magnetic disk manufactured using the subject glass substrate for a magnetic disk can satisfy a standard of a glide height of 15nm or less in a glide test. This is because since a glass substrate for a magnetic disk manufactured by the manufacturing method according to this invention has main surfaces with high smoothness and flatness, the smoothness and flatness of main surfaces are also improved in a magnetic disk manufactured using the subject glass substrate for a magnetic disk.

(Example)

Hereinbelow, a description will be given of an Example about a method of manufacturing glass substrate for a magnetic disk to which this invention is applied. Glass substrates for magnetic disks 100 to be packaged are intended to be manufactured as 2.5-inch disks. Alternatively, the glass substrates for magnetic disks 100 may be manufactured as magnetic disks having a predetermined shape, such as 0.8-inch disks (inner diameter 6mm, outer diameter 21.7mm, thickness 0.381mm), 1.0-inch disks (inner diameter 7mm, outer diameter 27.4mm, thickness 0.381mm), or 1.8-inch magnetic disks (inner diameter 12mm, outer diameter 48mm, thickness 0.508mm). The glass substrates for magnetic disks 100 may alternatively be applied to 3.5-inch disks.

(1) Shaping Process and First Lapping Process

In this example, as a material of glass substrates for a magnetic-disks 100, there can be cited sodalime glass, aluminosilicate glass, borosilicate glass, crystallized glass, or the like. Among them, the aluminosilicate glass is preferable. Since the aluminosilicate glass can obtain smoothness and high rigidity, the magnetic spacing, particularly the flying height of a magnetic head, can be reduced more stably. Further, the aluminosilicate glass can obtain high rigidity and strength by chemical strengthening.

First, molten aluminosilicate glass was formed into a disk shape by direct pressing using upper, lower, and drum molds, thereby obtaining an amorphous plate-like glass. As the aluminosilicate glass, use was made of a glass for chemical strengthening. Other than the direct pressing, disk-shaped glass substrates for magnetic-disks 100 may be obtained by cutting them out, using a grindstone, from a sheet glass formed by a downdraw method or a float method. As the aluminosilicate glass, use was made of a chemical strengthening glass containing, as main components,  $\text{SiO}_2$  : 58 to 75wt%,  $\text{Al}_2\text{O}_3$  : 5 to 23wt%,  $\text{Li}_2\text{O}$  : 3 to 10wt%, and  $\text{Na}_2\text{O}$  : 4 to 13wt%.

Then, lapping was applied to both main surfaces of the plate-like glass, thereby obtaining a disk-shaped glass base member. The lapping was carried out using a double-side lapping machine employing a planetary gear mechanism with the use of alumina-based free abrasive grains. Specifically, the lapping was carried out by pressing lapping surface plates onto both surfaces of the plate-like glass from the upper and lower sides, supplying a grinding fluid containing the free abrasive grains onto the main surfaces of the plate-like glass, and relatively moving them to each other. By this lapping, there was obtained the glass base member having the flat main surfaces.

## (2) Cutting-Out Process (Coring, Forming)

Then, the glass base member was cut using a diamond cutter, thereby

cutting out disk-shaped glass substrates for magnetic disks from the glass base member. Then, using a cylindrical diamond drill, an inner hole was formed at a central portion of each glass substrate for a magnetic disk, thereby obtaining annular glass substrates for magnetic disks 100 (coring). Then, grinding was applied to inner peripheral end faces and outer peripheral end faces 120 using diamond grindstones, thereby carrying out predetermined chamfering (forming).

### (3) Second Lapping Process

Then, second lapping was applied to both main surfaces 110 of each of the obtained glass substrates for magnetic disks 100 in the same manner as in the first lapping process. By performing this second lapping process, minute irregularities formed on the main surfaces in the cutting-out process or an end face polishing process as a previous process can be removed in advance, so that it becomes possible to complete a subsequent polishing process of the main surfaces 110 in a short time.

### (4) End Face Polishing Process

Then, outer peripheral end face polishing of the glass substrates for magnetic disks 100 was carried out. First, the end faces 120 were independently polished prior to chamfered faces 130. A polishing method may be, for example, a method of simultaneously polishing a plurality of the glass substrates for magnetic disks 100 using a brush, but the machining allowance becomes large. Therefore, use may be made of, for example, a single-wafer polishing method.

Subsequently, the chamfered faces 130 were mirror-polished. By this, the difference in surface roughness of the chamfered faces 130 of each glass substrate for a magnetic disk 100 over the entire circumference fell within the range of  $0.001\mu\text{m}$  or less. Thereafter, the glass substrates for magnetic disks 100 having been subjected to the end face polishing process were washed with

water. By this end face polishing process, the end faces 120 of the glass substrates for magnetic disks 100 were finished to a mirror surface state that can prevent precipitation of sodium and potassium.

In this Example, it has been described that the chamfered faces 130 were polished after the end faces were polished. However, this order is optional and it may be configured that the chamfered faces 130 are first polished and then the end faces 120 are polished.

Then, with respect to the inner peripheral end faces, it may be configured that a block is formed by stacking a number of the glass substrates for a magnetic disks and chamfered inner peripheral end portions are simultaneously polished using a brush roll. In this event, as polishing abrasive grains, use was made of a slurry (free abrasive grains) containing cerium oxide abrasive grains.

#### (5) Main Surface Polishing Process

A first polishing process was first carried out as a main surface polishing process. This first polishing process mainly aims to remove cracks or strains remaining on the main surfaces 110 during the above lapping processes. In this first polishing process, the main surfaces 110 were polished using a double-side polishing machine having a planetary gear mechanism with the use of a hard resin polisher. Cerium oxide abrasive grains were used as a polishing material.

The glass substrates for magnetic disks 100 having been subjected to the first polishing process were immersed in respective cleaning baths of neutral detergent, pure water, and IPA (isopropyl alcohol) in turn so as to be cleaned.

Then, a second polishing process was carried out as a main surface polishing process. This second polishing process aims to finish the main

surfaces 110 into mirror surfaces. In this second polishing process, the main surfaces 110 were mirror-polished using a double-side polishing machine having a planetary gear mechanism with the use of a soft resin foam polisher. As a polishing material, use was made of cerium oxide abrasive grains finer than the cerium oxide abrasive grains used in the first polishing process.

The glass substrates for magnetic disks 100 having been subjected to the second polishing process were immersed in respective cleaning baths of neutral detergent, pure water, and IPA (isopropyl alcohol) in turn so as to be cleaned. An ultrasonic wave was applied to each cleaning bath.

#### (6) Chemical Strengthening Process

Then, chemical strengthening was applied to the glass substrates for magnetic disks 100 having been subjected to the above lapping processes and polishing processes. The chemical strengthening was carried out by preparing a chemical strengthening solution in the form of a mixture of potassium nitrate (60%) and sodium nitrate (40%), heating this chemical strengthening solution to 400°C and preheating the cleaned glass substrates for a magnetic-disks 100 to 300°C, and immersing the glass substrates for a magnetic-disks 100 in the chemical strengthening solution for about 3 hours. In order to chemically strengthen the entire surfaces of the glass substrates for magnetic disks 100, the immersion was carried out in the state where the glass substrates for magnetic disks 100 were placed in a holder so as to be held at their end faces 120.

By performing the immersion process in the chemical strengthening solution as described above, lithium ions and sodium ions in the surface layers of each glass substrate for a magnetic-disk 100 are replaced by sodium ions and potassium ions in the chemical strengthening solution, respectively, so that the glass substrates for a magnetic-disks 100 are strengthened. The

thickness of a compressive stress layer formed in each surface layer of each glass substrate for a magnetic disk 100 was about 100 $\mu$ m to 200 $\mu$ m.

The glass substrates for magnetic disks 100 having been subjected to the chemical strengthening process were immersed in a water bath at 20°C so as to be rapidly cooled, and maintained for about 10 minutes. Then, the rapidly cooled glass substrates for magnetic disks 100 were immersed in concentrated sulfuric acid heated to about 40°C, so as to be cleaned. Further, the glass substrates for magnetic disks 100 having been subjected to the sulfuric acid cleaning were immersed in respective cleaning baths of pure water and IPA (isopropyl alcohol) in turn so as to be cleaned. An ultrasonic wave was applied to each cleaning bath.

By performing the first lapping process, the cutting-out process, the end face polishing process, the second lapping process, the first and second polishing processes, and the chemical strengthening process as described above, there were obtained the flat, smooth, and high-rigidity glass substrates for magnetic-disks 100.

#### (7) Inspection Process

Smoothness inspection was conducted for the main surfaces 110 of the obtained glass substrates for magnetic disks 100. Using an apparatus such as a surface defect detection apparatus (AOI : Automatic Optical Inspection) or an OSA (Optical Surface Analyzer), the inspection process irradiates light onto the glass substrate for a magnetic-disk 100, measures one or both of the intensity and displacement of light reflected from the glass substrate for a magnetic-disk 100 to determine whether or not adhering matter, a concave portion, or a convex portion exists, and evaluates the substrate state.

#### (8) Packaging Process

25 glass substrates for magnetic disks 100 were placed in each of

cases 200. The cases 200 in the number of four were, in a state of being arranged side by side, placed in a first packaging bag 210 made of an aluminum laminate film and two pipes 202 connected to a decompressor (not illustrated) were inserted into an opening portion of the first packaging bag 210, thereby decompressing and degassing the inside of the first packaging bag 210. In this event, the decompression rate was set to 0.1MPa/sec or less. Then, in the degassed state, the opening portion of the first packaging bag 210 was linearly bonded under heat and pressure so as to be hermetically closed by double heat sealings, thereby forming a package 212.

Then, the package 212 was placed in a second packaging bag 220 made of a plastic film and the inside of the second packaging bag 220 was decompressed and degassed. In this event, the decompression rate was set to about 0.05 to 0.1MPa/sec. Then, in the degassed state, an opening portion of the second packaging bag 220 was linearly bonded under heat and pressure so as to be hermetically closed by heat sealing, thereby forming a double package 222.

The double package 222 in which the glass substrates for a magnetic-disks 100 are placed in the cases 200 and double packaged with the first packaging bag 210 and the second packaging bag 220 as described above is shipped from a glass substrate manufacturing plant and transported to a magnetic disk manufacturing plant by a ship, an airplane, a train, or the like.

Of the double package 222, the second packaging bag 220 serving as the outside packaging bag was unpackaged in a predetermined room, thereby forming the package 212. This predetermined room is adjacent to another room and airflow is directed from this another room (illustration of the predetermined room and the another room is omitted).

Then, the first packaging bag 210 of the package 212 was unpackaged

in the another room. This another room is an intermediate room adjacent to the predetermined room and to a clean room in which the production line is provided, wherein the air flow is generated so as to be directed toward the predetermined room. When unpackaging the first packaging bag 210, a minute hole was opened in the first packaging bag 210 using a needle or the like so as to allow air to gradually flow into the first packaging bag 210. Then, after the air sufficiently flowed into the first packaging bag 210, the first packaging bag 210 was unpackaged.

[Evaluation]

A description will be given of effectiveness of this embodiment for the glass substrates unpackaged by the above processes. Fig. 6 shows graphs each illustrating the relationship between the decompression rate and the number of particles. In the packaging process of this embodiment, glass substrates were packaged by changing the condition of the decompression rate and, after the glass substrates were unpackaged in the manner described above, the 15 glass substrates were extracted from each case per decompression rate, thereby carrying out sampling.

Then, the number of particles of less than  $1.0\mu\text{m}$  adhering to the main surfaces of the glass substrates was counted using the surface defect detection apparatus (OSA6100) again and the average values thereof are shown in the graphs. Herein, an allowable value represents an upper limit of a value allowable as the number of particles with a size of less than  $1.0\mu\text{m}$  adhering to a main surface of a glass substrate to be used for a magnetic disk. A glass substrate exceeding this value is judged to be a defective product and thus cannot be used for a magnetic disk.

Fig. 6(a) shows the relationship between the decompression rate and the number of particles in the glass substrates to be used for magnetic disks

whose recording density is 200Gbit/inch<sup>2</sup>. As shown in Fig. 6(a), when the decompression rate is high, the number of particles on the main surface of the glass substrate largely exceeds the allowable value. On the other hand, when the decompression rate becomes 0.1MPa/sec, the number of particles on the main surface of the glass substrate first becomes 20, being the allowable value, or less. Therefore, it is seen that, by carrying out decompression and degassing at a decompression rate of 0.1MPa/sec or less when packaging the glass substrates, it is possible to prevent adhesion of particles to the main surfaces of the glass substrates and thus to improve the yield rate of the glass substrates for use in a magnetic disk manufacturing process.

Fig. 6(b) shows, as a Comparative Example, the relationship between the decompression rate and the number of particles in the glass substrates to be used for magnetic disks whose recording density is 60Gbit/inch<sup>2</sup>. As shown in Fig. 6(b), in the glass substrates to be used for magnetic disks whose recording density is 60Gbit/inch<sup>2</sup>, the allowable value of the number of particles on the main surface of the glass substrate is 60 count/surface. Further, the number of particles on the main surface of the glass substrate becomes the allowable value when the decompression rate becomes 0.3MPa/sec.

As described above, in the glass substrates to be used for magnetic disks whose recording density is about 60Gbit/inch<sup>2</sup>, the required standard of smoothness and flatness of the main surface is not so strict and thus the allowable value of the number of particles is high. Therefore, even by carrying out decompression and degassing at a decompression rate of about 0.3MPa/sec, the number of particles does not exceed the allowable value and thus the yield rate of the glass substrates does not largely decrease.

As described above, according to the method of manufacturing a glass substrate of this embodiment, it is possible to more reliably prevent dust

(particles) or foreign matter present in the packaging bag and the cases from adhering to the glass substrates. Therefore, a magnetic disk manufactured using this glass substrate has a reduced number of convex defects and thus can achieve a reduction in flying height of a magnetic head to even 10nm or less and an increase in recording density to 200Gbit/inch<sup>2</sup> or more.

While the preferred embodiment of this invention has been described with reference to the accompanying drawings, it is needless to say that this invention is not limited thereto. It is obvious that a person skilled in the art can think of various changed examples or modified examples within the scope of claims and it is readily understood that those examples also belong to the technical scope of this invention.

This invention is applicable to a method of manufacturing a glass substrate for magnetic disk.

## CLAIMS

1. A method of manufacturing a glass substrate for a magnetic disk, comprising:
  - placing one or more glass substrates for magnetic-disks in a case,
  - placing said case in a packaging bag,
  - degassing the inside of said packaging bag by performing decompression at a decompression rate of 0.1MPa/sec or less, and
  - sealing said packaging bag by hermetically closing an opening portion of said packaging bag in a degassed state.
2. A method of manufacturing a glass substrate for a magnetic disk according to claim 1, wherein said packaging bag is made of a metal laminate film.
3. A method of manufacturing a glass substrate for a magnetic-disk according to claim 1 or 2, wherein said hermetic closing is in a heat sealing manner of linear bonding under heat and pressure and comprises performing first hermetic closing and then further performing second hermetic closing inside a position of said first hermetic closing.
4. A method of manufacturing a glass substrate for a magnetic disk according to any one of claims 1 to 3, further comprising:
  - further placing in a second packaging bag said packaging bag sealed with said case placed therein,
  - degassing the inside of said second packaging bag by decompression, and
  - sealing said second packaging bag by hermetically closing an opening portion of said second packaging bag.
5. A method of manufacturing a glass substrate for a magnetic-disk

according to any one of claims 1 to 4, wherein said glass substrate for a magnetic-disk is used for manufacturing a magnetic disk that is recorded using a DFH (Dynamic Flying Height) head.

6. A method of manufacturing a glass substrate for a magnetic-disk according to any one of claims 1 to 5, wherein said glass substrate for a magnetic-disk is used for manufacturing a magnetic disk over which a flying height of a magnetic head is 10nm or less in recording on said magnetic disk.

7. A method of manufacturing a glass substrate for a magnetic-disk according to any one of claims 1 to 6, wherein said glass substrate for a magnetic-disk is used for manufacturing a magnetic disk with a recording density of 200Gbit/inch<sup>2</sup> or more.