DESCRIPTION

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

TECHNICAL FIELD

[0001] The present invention relates to a manufacturing method of glass substrate for magnetic disk used in a magnetic disk device such as hard disk device (HDD), and a manufacturing method of a magnetic disk using such glass substrate.

BACKGROUND ART

[0002] Recently, a glass substrate is used as one of the substrate for magnetic disk suited to high-density recording. The glass substrate is higher in rigidity as compared with a metal substrate, and is suited to application in high speed rotation of a magnetic disk device. Moreover, the glass substrate is capable of obtaining a smooth and flat surface, and is suited to application for higher S/N ratio and higher recording density, by lowering the floating amount of the magnetic head.

[0003] Generally, the glass substrate for magnetic disk is manufactured by executing sequentially a process of heating and melting a glass material to prepare molten glass, a process of forming this molten glass into a glass disk, and a process of processing and polishing the glass disk formed into a plate and manufacturing a glass substrate.

[0004] The process of forming the molten glass into a plate-shaped glass

disk is realized by press method, float method, and other forming methods. In the press method, from a circular columnar glass base material, a glass disk slightly larger in thickness than the substrate for magnetic disk is cut out, and is shaped into a glass disk, and is processed into a desired flatness and plate thickness. In the grinding process of processing the glass disk into a desired flatness and plate thickness, using a lapping device, the glass disk is ground to a target thickness and is processed to a target flatness. The glass disk is punched between an upper surface plate and a lower surface plate of the lapping device, and is processed by using free abrasive grains (slurry) while rotating in reverse direction. Free abrasive grains are abrasive grains of a particle size suited to the desired dimensional precision and shape precision of the glass disk, and in initial grinding process (lap 1), by using free abrasive grains of large particle size (for example, about 30 μm in average particle size), the plate is ground until a plate thickness of 0.92 mm, and in a second grinding process (lap 2: precision lapping process), by using free abrasive grains of smaller particle size (for example, about 10 μm in average particle size), the plate is ground until a plate thickness of 0.67 mm.

[0005] In the float process, a glass disk is cut out from the glass plate manufactured in the float process, and the shape of the glass disk is corrected, and the principal surface is ground and processed. The glass plate manufactured in the float process is initially finished to a mirror-smooth surface on the principal surface, and is superior in flatness and plate thickness as compared with the pressed glass. Hence, skipping lap 1 using free abrasive grains of large particle size, from the beginning it is intended to grind by using abrasive grains of smaller particle size (lap 2).

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[0006] In the grinding process of lap 2, by using fixed abrasive grains of smaller

particle size as compared with free abrasive grains, as a grinding pad, it is possible to make shallow the cracks occurring on the glass substrate, and the surface roughness can be reduced at the finishing point of grinding process of lap 2. For example, a diamond sheet having diamond particles adhered to a sheet is used as a grinding pad. The diamond particles to be used are smaller than the particle size of alumina grains used as free abrasive grains, and cracks are shallower, and the surface roughness is smaller.

[0007] Very fine abrasive grains are needed for polishing to a desired flatness, without worsening the surface roughness so far as possible, by processing the mirror-smooth glass of surface roughness of Ra = 0.001 μm or less such as plate glass manufactured by the float process. If attempted to process a mirror-smooth glass by using a grinding pad of such fine abrasive grains, at the beginning of processing, the processing rate must be suppressed to a very low speed (1/5 to 1/10 of ordinary processing rate), and the processing time is longer. Besides, in the initial stage of processing, deep flaws known as scratches are likely to be formed, and if the allowance is smaller than the depth of scratches, the scratches cannot be removed, and the quality is worsened.

[0008] As explained above, the problem of low processing rate in the starting process of polishing is not limited to the mirror-smooth plate glass manufactured in the float method, but it is a common problem seen in the process of processing the mirror-smooth plate glass by using a grinding pad of fine abrasive grains.

DISCLOSURE OF INVENTION

[0009] The invention is devised in the light of the above problems, and it is hence a primary object thereof to present a manufacturing method of glass substrate and a

manufacturing method of magnetic disk capable of realizing a high processing rate from start of processing, when processing the principal surface of a mirror-smooth plate glass by using fine fixed abrasive grains, shortening the processing time, and preventing occurrence of scratches.

[0010] The manufacturing method of glass substrate for magnetic disk of the invention has a surface grinding process for processing a mirror-smooth plate glass having a mirror-smooth surface on the principal surface, to a desired flatness and surface roughness by using fixed abrasive grains, and the surface grinding process using the fixed abrasive grains is preceded by a roughening process of roughening the mirror-smooth plate glass surface to a degree capable of being polished by the fixed abrasive grains by a mechanical method or a chemical method.

[0011] According to this manufacturing method, before the mirror-smooth glass plate surface is processed by using fixed abrasive grains, the mirror-smooth plate glass surface is roughened to a degree capable of being polished by the fixed abrasive grains by a mechanical method or a chemical method, and therefore bumps and hooks for fixed abrasive grains are formed on the mirror-smooth plate glass surface, and slipping of fixed abrasive grains on the mirror-smooth plate glass surface is prevented, and a high processing rate is realized from the beginning of processing by fixed abrasive grains.

[0012] The mechanical method in the roughening process includes a polishing process by using free abrasive grains. The chemical method includes a method of etching action by using a chemical solution. According to the mechanical method by using free abrasive grains, it is easy to control and manage the quality of the processed surface, and the chemical method of etching action by using a chemical solution can prevent occurrence of cracks. In particular, the chemical method of

etching action by using a chemical solution is preferred to be a frosting process. By this frosting process, the mirror-smooth plate glass surface can be efficiently roughened to a degree to be polished by fixed abrasive grains.

[0013] According to the manufacturing method of glass substrate for magnetic disk of the invention, the roughening process is preferred to roughen the mirror-smooth plate glass surface having a mirror-smooth surface roughness of Ra = 0.001 μm or less, to surface roughness of Ra = 0.01 to 0.4 μm.

[0014] In the manufacturing method of glass substrate of the invention, the roughening process is preferred to roughen the mirror-smooth plate glass to the condition of $B/A < 50$, where A is the surface roughness of the glass and B is the average particle size of the fixed abrasive grains. According to this manufacturing method, by satisfying the condition of $B/A < 50$, the mirror-smooth plate glass surface can be roughened to a degree to be polished by fixed abrasive grains.

[0015] According to the manufacturing method of glass substrate for magnetic disk of the invention, the process of processing the mirror-surface plate glass surface by using the fixed abrasive grains is preferred to process to the surface roughness of Ra = 0.1 μm or less and the flatness of 7 μm or less.

[0016] In the manufacturing method of glass substrate of the invention, at least a magnetic layer is formed on a principal surface of the glass substrate manufactured by the manufacturing method of the glass substrate described above.

[0017] According to the invention, when polishing the principal surface of the mirror-smooth plate glass, a high processing rate is realized from the beginning of the polishing process, and the processing time is shortened, and occurrence of scratches can be prevented at the same time.

BRIEF DESCRIPTION OF DRAWINGS

[0018] Fig. 1 is a schematic diagram of a part of process of a manufacturing method of glass substrate for magnetic disk in a preferred embodiment of the invention.

Fig. 2 is a schematic diagram of a diamond sheet.

Fig. 3 is a diagram showing the processing rate by precision lapping by using fixed abrasive grains depending on presence or absence of roughening process.

Fig. 4 is a schematic diagram of a glass substrate for magnetic disk.

Fig. 5 is a schematic diagram of a process of a manufacturing method of glass substrate for magnetic disk in a preferred embodiment of the invention.

Fig. 6 is a diagram of evaluation results of a preferred embodiment and a comparative example.

BEST MODE FOR CARRYING OUT THE INVENTION

[0019] (Preferred embodiment 1)

A preferred embodiment of the invention relates to a manufacturing method of a glass substrate for magnetic disk and a manufacturing method of a magnetic disk. In the following explanation, the material of the glass substrate for magnetic disk is a plate glass material manufactured by a float process. However, the invention is not limited to the plate glass material manufactured by a float process, but may be applied to any mirror-smooth plate glass manufactured by other methods. The application is not limited to the glass substrate for magnetic disk alone, and the invention may be similarly applied to other mirror-smooth plate glass surfaces processed by fine fixed abrasive grains as far as the surface flatness and surface roughness are as desired. Herein, the mirror-smooth surface refers to any surface having a surface roughness (arithmetic average roughness (Ra)) of 0.01 μm or less.

[0020] In the manufacturing method of a glass substrate for magnetic disk in the preferred embodiment, the plate glass material of which principal surface is a mirror-smooth surface is processed by roughening the mirror-smooth surface of the plate glass surface by mechanical or chemical method until the fixed abrasive grains may polish effectively on the surface (mirror-smooth surface) of the plate glass material.

[0021] The mechanical method for roughening the plate glass material mirror-smooth surface includes polishing by using free abrasive grains by a surface polishing machine. By using free abrasive grains, the entire surface of the mirror-smooth plate glass is polished to a nearly uniform surface roughness Ra = 0.01 to 0.4 μm. Advantages of roughening by the mechanical method include ease of control and management of the quality of the processed surface.

[0022] The chemical method for roughening the plate glass material mirror-smooth surface includes a method of making use of an etching action by using a chemical solution. The chemical solution to be used in the chemical method includes acidic ammonium fluoride and hydrofluoric acid. By the etching action of acidic ammonium fluoride or hydrofluoric acid, the plate glass material mirror-smooth surface can be roughened. Advantages of roughening by the chemical method include freedom from cracks. It is also low in the initial cost when installing the equipment and it is easy to automate. Frosting process is particularly preferred as the chemical method of roughening the plate glass material mirror-smooth surface. Herein, the frosting process is a method of processing the glass surface by using a chemical solution for etching adding a roughening agent. In this frosting process, etching is progressed in a state of the glass surface masked locally by the roughening agent, and the glass surface can be roughened effectively (for example, surface roughness Ra after the

frosting process is about 5 times of surface roughness Ra before the frosting process). The roughening agent may be any compound capable of supplying HF_2^- in the solution, such as HF, NH_4F, NaF, KF, CaF_2, etc. Also by adjusting the concentration or temperature of the chemical solution, the state of roughening can be adjusted.

[0023] The plate glass material of which mirror-smooth surface is roughened is ground by using fixed abrasive grains until achieving the desired surface flatness and thickness. The fixed abrasive grains are preferred to be finer abrasive grains than the free abrasive grains. Supposing the surface roughness of the plate glass material to be "A" and the average particle size of the fixed abrasive grains to be "B", it is desired to satisfy the relation of $(B/A) < 50$.

[0024] In a preferred embodiment, in order to remove flaws and strains left over after the grinding process by using fixed abrasive grains, by using a hard polisher as a polisher, a first polishing process of polishing the glass substrate surface is followed by a second polishing process of polishing the glass disk surface by a soft polisher, instead of the hard polisher, for finishing to a smoother mirror-smooth surface while maintaining the flat surface obtained in the first polishing process.

[0025] The glass substrate finishing the polishing process may be reinforced chemically. In particular, in the case of the glass material of alumino-silicate glass, by chemical reinforcement, the rupture strength is increased, and the depth of compressive stress layer is deepened. The method of chemical reinforcement is not particularly specified as far as known conventionally, and substantially a chemical reinforcement method by low-temperature ion exchange method is preferred.

[0026] In the manufacturing method of the glass substrate for magnetic disk, before processing of the mirror-smooth plate glass surface by using fixed abrasive grains (before the grinding process of principal surface), the mirror-smooth plate glass

surface is roughened by a mechanical method or a chemical method until polishing action by the fixed abrasive grains is effective. As a result, bumps and lumps for hooking of fixed abrasive grains are formed on the mirror-smooth plate glass surface, and slipping of fixed abrasive grains on the mirror-smooth plate glass surface can be prevented. Hence, in the surface grinding process, a high processing rate is realized from the beginning of the process by fixed abrasive grains.

[0027] In the principal surface grinding process, the mirror-smooth plate glass surface is processed by using fixed abrasive grains. In this case, preferably, the surface roughness Ra is 0.1 μm or less, and the flatness is 7 μm or less.

[0028] On the glass substrate for magnetic disk obtained by the invention, at least a magnetic layer is formed, and a magnetic disk suited to high recording density is obtained.

[0029] The material of the magnetic layer is, for example, CoPt system ferromagnetic alloy known as hexagon system large in anisotropic magnetic field. The forming method of magnetic layer includes a sputtering method, for example, a method of forming a magnetic layer on the glass substrate by DC magnetron sputtering method. By inserting a base layer between the glass substrate and the magnetic layer, it is possible to control the orientation direction of magnetic grains in the magnetic layer, or the size of magnetic grains.

[0030] It is also preferred to form a protective layer on the magnetic layer. By forming the protective layer, the magnetic disk surface can be protected from the magnetic recording head floating and flying on the magnetic disk. The material of the protective layer is preferably a carbon compound protective layer. It is further preferred to form a lubricating layer on the protective layer. By forming the lubricating layer, friction between the magnetic recording head and the magnetic disk

can be suppressed, and the durability of the magnetic disk can be enhanced. The material of the lubricating layer is preferably, for example, PFPE (perfluoropolyether).

[0031] According to the invention, from the plate glass obtained in the float method, it is possible to manufacture stably glass substrates to be used in magnetic disks to be mounted on a magnetic disk device of load-unload type advantageous for high recording density. By manufacturing a magnetic disk by using the glass substrate for magnetic disk obtained by the manufacturing method of the invention, the manufacturing yield of the glass substrates for magnetic disk is high, and the manufacturing cost of the magnetic disks can be lowered.

[0032] (Exemplary embodiment 1)

The preferred embodiment of the invention is described specifically below by referring to exemplary embodiments. It must be noted, however, that the invention is not limited by the following exemplary embodiments alone.

[0033] The glass substrate for magnetic disk of this exemplary embodiment was manufactured as follows in the procedure consisting of (1) cutting process, (2) shaping process, (3) roughening process, (4) precision lapping process, (5) end face polishing process, (6) principal surface polishing process, and (7) chemical reinforcing process. The concept of the process from (1) to (4) is shown in Fig. 1.

[0034] The plate glass material for manufacturing a glass substrate for magnetic disk was produced by float method. In the float method, a fusion solution was poured on molten tin, and was solidified directly. The both sides of the plate glass are a free surface of glass and an interface of glass/tin, and were not polished, and a plate glass material having a mirror-smooth surface of Ra = 0.001 μm or less was obtained.

[0035] (1) Cutting process

A plate glass material 1 of alumino-silicate glass of thickness of 0.95 mm manufactured by the float method was cut to a square shape of specified size, and its top surface was processed by a glass cutter, and circular cutting lines 2 were formed to draw outer and inner peripheral edges of the region as the glass substrate for magnetic disk. This alumino-silicate glass was a chemically reinforced glass containing SiO_2 : 58 mass % to 75 mass %, Al_2O_3 : 5 mass % to 23 mass %, Li_2O : 3 mass % to 10 mass %, and Na_2O : 4 mass % to 13 mass %. The top surface of the plate glass 1 forming such cutting lines 2 was entirely heated by a heater, and the cutting lines 2 were advanced to the bottom side of the plate glass 1, and a glass disk (mirror-smooth plate glass) 3 having a specified diameter was cut out.

[0036] (2) Shaping process

By grinding the outer circumferential end face and the inner circumferential end face, the outside diameter was finished to 65 mm, and the inside diameter (the diameter of the circular hole in the central part) was finished to 20 mm, and the outer circumferential end face and the inner circumferential end face were chamfered as specified. At this time, the surface roughness of the glass disk end face was Rmax of about 2 μm. Generally, in the 2.5 (inch) type HDD (hard disk drive), a magnetic disk of outside diameter of 65 mm is used.

[0037] (3) Roughening process

A mechanical method of using free abrasive grains by a surface polishing machine was applied. Using free abrasive grains, the entire surface of the mirror-smooth glass disk 3 was polished until a uniform surface roughness of Ra = 0.01 μm to 0.4 μm. The target surface roughness in the roughening process is desired to be determined in relation to the particle size of the fixed abrasive grains to be used in the subsequent precision lapping process. As mentioned above, the

average particle size B of the fixed abrasive grains is divided by the surface roughness (A) of the roughened glass disk 3, the relation of (B/A) < 50 is satisfied. Herein, the surface roughness of the glass substrate was Ra = 0.27 μm.

[0038] (4) Precision lapping process

The principal surface of the roughened glass disk 3 polished by using a fixed abrasive grain polishing pad. The fixed abrasive grain polishing pad was a diamond sheet 10 as shown in Fig. 2. The diamond sheet 10 contains diamond particles as abrasive grains. The diamond sheet 10 has a PET sheet 11 as a base material. The average particle size of diamond grains 12 was B = 4 μm. Therefore, B/A = 15, which satisfies the requirement of (B/A) < 50.

[0039] In the precision lapping process, the roughened glass disk 3 was set in a lapping machine, and the disk surface was lapped by using the diamond sheet 10 as shown in Fig. 3, and was processed to surface roughness Ra of 0.1 μm or less and flatness of 7 μm or less at high processing rate.

[0040] In this manner, since the principal surface of the glass disk 3 is preliminarily roughened in the roughening process, bumps as hooks for fine fixed abrasive grains are formed on the principal surface of the glass disk 3, slipping of fixed abrasive grains on the material surface can be prevented, and the processing rate in the precision lapping process is realized at a high rate from the beginning of the surface polishing process.

[0041] (5) End face polishing process

Successively, by brush polishing, the surface of end faces (inside, outside) of the glass disk 3 was polished while rotating the glass disk 3 to roughness of about Rmax of 0.4 μm and Ra of 0.1 μm. After the end face polishing, the surface of the glass disk 3 was washed in water.

[0042] (6) Principal surface polishing process

To remove flaws and strains left after the lapping process, a first polishing process was executed by using a double-sided polishing machine. In the double-sided polishing machine, the glass disk 3 holding the carrier between upper and lower polishing surface plates to which polishing pads are adhered is placed in contact, and this carrier is engaged between the planet gear and the inner gear, and the glass disk is suppressed by the upper and lower polishing surface plates. Consequently, a polishing solution is poured into the space between the polishing pad and the polishing surface of the glass disk, and by rotating, the glass disk rolls on the polishing surface plate and rotates, and the both surfaces are polished at the same time. More specifically, a hard polisher (hard foamed urethane) is used as the polisher, and the first polishing process was executed.

[0043] Next, by using the same double-sided polishing machine as used in the first polishing process, a second polishing process was executed by replacing the polisher by a polishing pad of soft polisher (suede). In this second polishing process, while maintaining the flat surface obtained in the first polishing process, this is a mirror-smooth surface polishing process for finishing the principal surface of the glass disk to a smooth mirror-smooth surface of surface roughness of Rmax 3 nm or less.

[0044] (7) Chemical reinforcing process.

The washed glass disk was reinforced chemically. Ions existing on the surface of the glass substrate (for example, in the case of alumino-silicate glass, Li^+ and Na^+) are exchanged with ions of larger ion radius (Na^+ and K^+). On the surface of the glass substrate (for example, up to about 5 μm from the glass substrate surface), by ion exchange with atoms of larger ion radius, a compressive stress is applied to the glass surface, and thereby the rigidity of the glass substrate is

enhanced. In this manner, the glass substrate for magnetic disk in the embodiment was obtained.

[0045] By forming a film as follows on the glass substrate for magnetic disk obtained in the embodiment, a magnetic disk was obtained. By using a sputtering device, on the glass substrate, a bonding film, a soft magnetic film, a first base layer, a second base layer, and a magnetic layer were formed sequentially, and next by plasma CVD method, a carbon compound protective layer was formed, and further a lubricating layer was formed thereon by a dipping method.

[0046] The bonding film was formed as a Ti alloy thin film in a film thickness of 10 nm, the soft magnetic film was formed as a Co alloy thin film in a film thickness of 60 nm, the first base layer was formed as a Pt alloy thin film in a film thickness of 7 nm, the second base layer was formed as a Ru alloy thin film in a film thickness of 40 nm, and the magnetic layer was formed as a CoPtCr alloy thin film in a film thickness of 20 nm. The protective layer was formed as a diamond-like carbon protective layer, by plasma CVD method. The lubricating layer was formed by immersing the magnetic disk in a liquid lubricating agent of perfluoropolyether (PFPE), and heating for 60 minutes at temperature of 110°C. In this manner, the magnetic disk of vertical magnetic recording method was formed.

[0047] (Comparative example 1)

Same as in exemplary embodiment 1, a plate glass material 1 was manufactured from alumino-silicate glass of 0.95 mm in thickness by float method, and was processed by the cutting process and the shaping process, and also by precision lapping process by using fixed abrasive grains, but the roughening process was skipped. The processing rate in the precision lapping process was investigated, and it was very low as shown in Fig. 3.

[0048] (Exemplary embodiment 2)

In the manufacturing process of the glass substrate for magnetic disk, by rotating an internal gear and an external gear, and supplying a slurry containing free abrasive grains in a grinding solution on the principal surface of the work, the principal surface of the glass substrate contained in the carrier is ground (rough lapping process). A hole is drilled in a central part of the glass substrate, and the outer circumferential end face and the inner circumferential end face are chamfered as specified, and the shape is processed (end face shaping process). The chamfered glass substrate is ground on the principal surface of the glass substrate by using free abrasive grains of smaller particle size than the free abrasive grains used in the rough lapping process (precision lapping process). Further, in order to remove flaws and strains left over after the precision lapping process, the principal surface of the glass substrate is polished (polishing process).

[0049] In the lapping process, free abrasive grains may get in between the carrier and the glass substrate, and the end surface of the glass substrate may be scratched or cracks. Accordingly, for the purpose of removing the flaws formed on the end surface in the lapping process, too, the end surface polishing process is executed after the lapping process.

[0050] However, if precision lapping process is executed after polishing the edge portion in the end surface polishing process, damages are large on the ridge portion on the boundary of the principal surface and the end surface of the glass substrate, and defects may be formed from the ridge portions. Accordingly, the end surface polishing process is executed after the precision lapping process, and the risk of defects on the ridge portions in the edge polishing process is avoided.

Patent Document 1: Japanese Laid-Open Patent Publication No. 2002-55061

Patent Document 2: Japanese Laid-Open Patent Publication No. 2007-115389

[0051] In the edge portion polishing process, however, since a plurality of glass substrates are mounted on a polishing tool with the principal surfaces placed face to face, the substrate surfaces may be bruised when overlapping the glass substrates although a high surface quality is demanded. On the other hand, if the end surface polishing process is followed by the precision lapping process of surface grinding process by using free abrasive grains, the damage on the substrate end surface is large, and in order to avoid defects on the ridge portions, it was forced to execute the end surface polishing process after the precision lapping process.

[0052] The exemplary embodiment presents a manufacturing method of a glass substrate for magnetic disk and a manufacturing method of a magnetic disk capable of removing flaws formed on the substrate surface within the process to enhance the surface quality, and capable of removing damages in the substrate edge portion.

[0053] The manufacturing method of a glass substrate for magnetic disk of the invention includes an end surface polishing process of polishing the end surface of the glass substrate to remove flaws on the end surface, and a surface grinding process of using fixed abrasive grains for grinding and processing the principal surface of the glass substrate after the end polishing process to a desired surface roughness and flatness.

[0054] According to this manufacturing method, since the end surface polishing process is followed by the surface grinding process, flaws formed on the substrate surface can be removed in the surface grinding process after the end surface polishing process when joining the glass substrates, and the surface quality can be improved. Moreover, in the surface grinding process, since fixed abrasive grains are used in surface grinding process, as compared with the process of using free abrasive

grains, there is no damage on the edge of the glass substrate, and flaws on edge portion of glass substrate can be eliminated. The fixed abrasive grains used in the surface grinding process are smaller in particle size than the free abrasive grains, and the surface grinding amount in the later process can be lessened. Further, since the end surface polishing process is followed by the surface grinding process, plural processes for grinding and polishing the end surfaces of the glass substrate, and plural processes for grinding and polishing the principal surface of the glass substrate can be done continuously, and the process design is easier.

[0055] The manufacturing method of a glass substrate for magnetic disk of the invention further includes a principal surface polishing process of polishing the principal surface of the glass substrate after the surface grinding process, and the particle size of the polishing grains used in the end surface polishing process is larger than the particle size of the polishing grains used in the principal surface polishing process.

[0056] The manufacturing method of a glass substrate for magnetic disk of the invention may be applied in both the glass substrate manufactured in the float method and the glass substrate manufactured in the press method. However, when the glass substrate is a mirror-smooth plate glass of which principal surface is a mirror-smooth surface, in the precision lapping process by fixed abrasive grains, since surface roughness Ra of the mirror-smooth plate glass is low, the fixed abrasive grains may not be hook but slip, and the processing rate may be lower. In such a case, when using a mirror-smooth plate glass having a mirror-smooth surface on the principal surface as the glass substrate, same as in exemplary embodiment 1, the precision lapping process may be preceded by a roughening process of roughening the principal surface of the glass substrate. As a result, bumps for hooking the fixed

abrasive grains are formed on the surface of mirror-smooth plate glass, and slipping of fixed abrasive grains on the surface of mirror-smooth plate glass can be prevented. As a result, in the precision lapping process, a high processing rate is realized from the beginning of processing by fixed abrasive grains.

[0057] In the roughening process, same as in exemplary embodiment 1, the plate glass material having a mirror-smooth surface on the principal surface is roughened by a mechanical method or a chemical method, so that fixed abrasive grains may be effective in polishing action on the surface (mirror-smooth surface) of the plate glass material.

[0058] The mechanical method of roughening the mirror-smooth surface of the plate glass material is realized by polishing by free abrasive grains by using a surface polishing machine same as in exemplary embodiment 1. The chemical method of roughening the mirror-smooth surface of the plate glass material is realized by etching action by using a chemical solution same as in exemplary embodiment 1. In particular, as the chemical method of roughening the mirror-smooth surface of the plate glass material, frosting process is preferred same as in exemplary embodiment 1.

[0059] The manufacturing method of a magnetic disk of the invention is characterized by forming at least a magnetic layer on the principal surface of the glass substrate for magnetic disk manufactured in the manufacturing method of the glass substrate for magnetic disk. According to this manufacturing method, flaws of the substrate surface are removed, and the magnetic layer can be formed on the glass substrate for magnetic disk free from flaws on the edge portion of the glass substrate, so that a magnetic disk high in rigidity and excellent in smoothness can be obtained.

[0060] According to the exemplary embodiment, flaws formed on the substrate

surface when joining the substrate surfaces on the glass substrate can be removed later in the surface grinding process after the end surface polishing process, and if the surface grinding process is executed after the end surface polishing process, damage on edge portion of the glass substrate can be eliminated, and the phenomenon of defect of ridge portion of the glass substrate can be avoided.

[0061] The manufacturing method of a glass substrate for magnetic disk of the exemplary embodiment is intended to manufacture a glass substrate for magnetic disk to be used as the glass substrate for a magnetic disk mounted on HDD or the like. This magnetic disk is a recording medium capable of recording and reproducing information signals of high density by, for example, a vertical magnetic recording system.

[0062] The glass substrate for magnetic disk measures 15 mm to 30 mm in outside diameter, 5 mm to 12 mm in inside diameter, and 0.35 mm to 0.5 mm in plate thickness, and it is manufactured, for example, as a magnetic disk having a specified diameter, such as 0.8 inch type magnetic disk (inside diameter 6 mm, outside diameter 21.6 mm, plate thickness 0.381 mm), or 1.0 inch type magnetic disk (inside diameter 7 mm, outside diameter 27.4 mm, plate thickness 0.381 mm). Magnetic disks may be also manufacture as 2.5 inch type magnetic disk, or 3.5 inch type magnetic disk. The inside diameter refers to the internal diameter of the circular hole in the center of the glass substrate.

[0063] Fig. 4 is a perspective view showing a configuration of a glass substrate for magnetic disk manufactured in the manufacturing method of a glass substrate for magnetic disk according to the invention. As shown in Fig. 4, this is a manufacturing method of a glass substrate for magnetic disk for manufacturing a glass substrate 21 for magnetic disk having a circular hole 22 in the central part. This glass substrate

21 for magnetic disk is made of a glass material, and an excellent smoothness is realized by mirror-smooth surface polishing, and moreover since the hardness is high and the rigidity is high, it is excellent in resistance to impact. The glass is a brittle material, but may be enhanced in breakdown strength by chemical reinforcement, cold wind reinforcement, or other reinforcing process, or crystallizing means.

[0064] As the material for such glass substrate, a preferred glass is alumino-silicate glass. The alumino-silicate glass can realize an excellent surface smoothness, and is also enhanced in breakdown strength by chemical reinforcement or the like.

[0065] The alumino-silicate glass is preferably a chemically reinforced glass mainly composed of SiO_2: 62 wt.% to 75 wt.%, Al_2O_3: 5 wt.% to 15 wt.%, Li_2O: 4 wt.% to 10 wt.%, Na_2O: 4 wt.% to 12 wt.%, and ZrO_2: 5,5 wt,% to 15 wt.%, with the weight ratio of Na_2O and ZrO_2 of 0.5 to 2.0, and the weight ratio of Al_2O_3 and ZrO_2 of 0.4 to 2.5.

[0066] The material for the glass substrate for magnetic disk to be manufactured in the invention is not limited to the material mentioned above. That is, aside from the alumino-silicate glass, the material of the glass substrate may include, for example, soda lime glass, soda alumino-silicate glass, amino boro-silicate glass, boro-silicate glass, quartz glass, chain silicate glass, crystallized glass, and other glass ceramics.

[0067] In the manufacturing method of a glass substrate for magnetic disk of the invention, the sequence of processes may be exchanged, for example, the surface grinding process following the end surface shaping process may be replaced by the surface grinding process by using fixed abrasive grains, or the surface grinding process may be executed after the end surface polishing process.

[0068] The manufacturing process of a glass substrate for magnetic disk is usually executed in the sequence of precision lapping process, end surface polishing process, and principal surface polishing process (first polishing process). The particle size of

abrasive grains (free abrasive grains) to be used in each process becomes smaller in the sequence of precision lapping process, end surface polishing process, and principal surface polishing process. As in this exemplary embodiment, when the surface grinding process is executed after the end surface polishing process, flaws may be formed on the end surface after the end surface polishing because the particle size of the free abrasive grains used in the surface grinding process is larger than the particle size of the free abrasive grains used in the end surface polishing process. However, in the exemplary embodiment, in the surface grinding process, since the surface is ground by using fixed abrasive grains, the end surface after end surface polishing will not be bruised if the surface grinding process is done after the end surface polishing process. Hence, the quality off the glass substrate is not spoiled, and plural processes for grinding and polishing the end surfaces of the glass substrate, and plural processes for grinding and polishing the principal surface of the glass substrate can be done continuously, and the process design is easier.

[0069] From the viewpoint of particle size of abrasive grains and flawing as mentioned above, the particle size of abrasive grains used in the end surface polishing process is preferred to be larger than the particle size of abrasive grains used in the principal surface polishing process (first polishing process) for polishing the principal surface of the glass substrate after the surface grinding process.

[0070] (Exemplary embodiment 2)

A second exemplary embodiment of manufacturing method of a glass substrate for magnetic disk and manufacturing method of a magnetic disk is explained below in the sequence of processes. Fig. 5 is a diagram showing a process sequence of the manufacturing method of a glass substrate for magnetic disk in this exemplary embodiment.

[0071] (1) Rough lapping process (step S1)

For example, when manufacturing a glass substrate for magnetic disk of 2.5 inch type magnetic disk, a circular glass material of 66.2 mm in diameter and 1.15 mm in thickness is prepared. The circular glass material as a glass substrate is put into a carrier of a lapping machine, and the inner gear and the outer gear are rotated, and a mixed slurry of grinding fluid and free abrasive grains is supplied onto the principal surface of the work, and the principal surface of the glass substrate contained in the carrier is ground. In this lapping process, as free abrasive grains, alumina abrasive grains of grain size (roughness) of #800 and particle size of 9 μm to 38 μm are used, and the surface is ground and processed until a plate thickness of 0.756 mm.

[0072] The circular glass material is a glass substrate of alumino-silicate glass being cut out from a sheet glass formed by down-draw method, into a circular shape, and it is ground and processed by relatively coarse diamond grains, and is formed into a disk of 65.7 mm in diameter and 0.915 mm in thickness. Instead of the down-draw method, a circular glass material may be obtained from a sheet glass formed by float method, by cutting out similarly in a circular shape, and pressing the molten glass directly by using upper pattern, lower pattern, and shell.

[0073] (2) End surface shaping process (step S2)

A hole is drilled in the central portion of the glass substrate, and the outer edge and the inner edge are chamfered. Using a cylindrical grindstone, a hole is drilled in the central portion of the glass substrate, and the outer edge is also ground until the diameter is 65 mm, and the outer edge and the inner edge are chamfered as specified. At this time, the surface roughness of the edge portions (lateral side and chamfered portion) of the glass substrate was Rmax of about 1.5 μm.

[0074] (3) End surface polishing process (step S3)

A plurality of glass substrates were mounted on a polishing machine, by joining the principal surfaces, and polished by brushing while rotating the glass substrates until the surface roughness of the edge portions (corner parts, lateral side and chamfered portion) of the glass substrate became about Rmax of 1 μm and Ra of 0.3 μm. This end surface polishing process is effective for preventing defects under the film occurring due to sticking of dust particles on the glass substrate principal surface from the substrate edge portions occurring at the time of conveying the glass substrate or in the washing process. After the end surface polishing process, the glass substrate was washed in water.

[0075] (4) Surface grinding process (fixed abrasive grains) (step S4)

By using fixed abrasive grains, the principal surface of the glass substrate is ground to a desired plate thickness of 0.656 mm and flatness of < 3 μm. The principal surface of the glass substrate was ground by using a fixed abrasive grain polishing pad. For example, a diamond sheet can be used as the fixed abrasive grain polishing pad. The fixed abrasive grain polishing pad has polishing particles adhered on a sheet, and sufficiently smaller particles (< 4 μm) can be used as compared with alumina grains (10.0 μm to 10.6 μm) used in free abrasive grains.

[0076] When fixed abrasive grains are used in the surface grinding process, since polishing grains are fixed on the sheet, unlike free abrasive grains, particles will not get in between the carrier and the glass substrate. Since particles are not present between the carrier and the glass substrate, it is possible to eliminate damages due to secondary factors, such as scratch or crack on the edge portion of the glass substrate. As a result, damages can be eliminated from the ridge portions on the boundary of the surface and edges of the glass substrate, and phenomenon of defect in the ridge portion can be prevented. Since the phenomenon of defect in the ridge portion can

be prevented, it is possible to save the polishing allowance for the surface and edges.

[0077] Flaws formed on the principal surface when joining the principal surfaces of the glass substrates in the end surface polishing process can be eliminated in the later process of surface grinding by using fixed abrasive grains. Moreover, since the surface is ground after the end surface grinding, if the edge portion is stepped by excessive polishing in the end surface polishing process, the stepped portion of the edge can be cleared in the later surface grinding process. Further, by grinding the surface by using fixed abrasive grains, as compared with free abrasive grains, the surface roughness of the glass substrate can be decreased. Hence, the polishing amount in the later process of principal surface polishing process can be saved.

[0078] (5) Principal surface polishing process (step S5)

In order to remove the flaws and strains left over after the surface grinding process, a first polishing process was executed by using a two-sided polishing machine. In the two-sided polishing machine, between upper and lower polishing surface plates provided with polishing pads, the glass substrate held by the carrier is placed tightly, and the carrier is engaged with a planet gear and an inner gear, and the glass substrate is held and pressed between the upper and lower surface plates. Subsequently, a polishing fluid is supplied between the polishing pads and the polishing surface of the glass substrate, and by rotating, the glass disk rotates on the polishing surface plates, and revolves to polish the both sides simultaneously. More specifically, a hard polisher (hard foamed urethane polisher) was used, and the first polishing process was executed.

[0079] By using the same two-sided polishing machine as used in the first polishing process, the polisher was changed to a soft polisher (suede polisher), and a second polishing process was executed by using the new polishing pads. The second

polishing process is a mirror-smooth surface polishing process for finishing to a smooth mirror-surface while maintaining the flat surface obtained in the first polishing process.

[0080] Thus, by exchanging the sequence of the end surface polishing process and the surface grinding process (fixed abrasive grains), processes for grinding and polishing the end surfaces can be done continuously such as end surface shaping process, or processes for grinding and polishing the principal surface can be done continuously such as surface grinding process (fixed abrasive grains) and principal surface polishing process, and the process design is easier.

[0081] (6) Chemical reinforcing process (step S6)

After the washing process, the glass substrate was reinforced chemically. Ions existing on the surface of the glass substrate (for example, Li^+ and Na^+ in the case of alumino-silicate glass) are exchanged with ions of larger ion radius (Na^+ and K^+). On the surface of the glass substrate (for example, about 5 μm from the glass substrate surface), by exchanging with ions of atoms of larger ion radius, a compressive stress is applied to the glass surface, so that the rigidity of the glass substrate may be enhanced.

[0082] (7) Washing process (step S7)

Polishing materials and impurities are sticking to the surface of the glass substrate, and they are removed by washing. The washing method includes physical washing and chemical washing. The physical washing includes scrub washing and ultrasonic washing. The chemical washing includes etching of glass substrate, chemical solution washing for dissolving impurities and polishing materials sticking to the glass substrate, and potential control washing by using a surface active agent. In Fig .1, this process is specified after the chemical reinforcing process, but it

is not specified, and the washing process may be executed anywhere appropriately between the grinding process to the first polishing and second polishing process.

[0083] (8) Inspection process (step S8)

The inspection process includes 100% inspection and sampling inspection. Where possible, 100% inspection is applied, and if not possible, sampling inspection is applied. Defects to be inspected are flaws, stains (particles), material defect, and deformation. In Fig .1, this process is specified after the chemical reinforcing process, but it is not specified, and the washing process may be executed anywhere appropriately between the grinding process to the first polishing and second polishing process. In a clean-room, by using an AFM (atomic force microscope), the surface state of glass substrate is inspected, and ID and OD chamfering angles are measured, and the roundness and concentricity are measured. After the washing process following the second polishing process, the glass substrate is brought into a clean-room, and is inspected visually. At this time, the glass substrate is inspected for presence or absence of crack, dust, cut, crevice, or remaining polishing materials. After the washing process following the chemical reinforcing process, the glass substrate is similarly inspected visually. By such defect inspection, the both sides of the glass substrate are judged whether to satisfy or not the required specification of the recording surface. In this manner, the glass substrate for magnetic disk of the exemplary embodiment was obtained.

[0084] In the glass substrate for magnetic disk obtained in the exemplary embodiment, films were formed in the following process, and a magnetic disk was obtained. By using a sputtering device, a bond layer, a soft magnetic layer, a first base layer, a second base layer, and a magnetic layer were formed on the glass substrate, and a carbon protective layer was formed by plasma CVD method, and

further a lubricating layer was formed thereon by a dip method.

[0085] The bond layer was a Ti alloy thin film formed in a film thickness of 10 nm, the soft magnetic layer was a Co alloy thin film formed in a film thickness of 60 nm, the first base layer was a Pt alloy thin film formed in a film thickness of 7 nm, the second base layer was a Ru alloy thin film formed in a film thickness of 40 nm, and the magnetic layer was a CoPtCr alloy thin film formed in a film thickness of 20 nm. The protective layer was diamond-like carbon protective layer formed by plasma CVD method. The lubricating layer was formed by immersing the magnetic disk in a liquid lubricant of perfluoropolyether (PFPE), and by heating and baking for 60 minutes at 110°C. In this manner, the magnetic disk for vertical magnetic recording system was manufactured.

[0086] The glass substrate for magnetic disk obtained in exemplary embodiment is compared with the glass substrates manufactured in the following comparative examples 2 to 4, and the evaluations results are discussed.

[0087] (Comparative example 2)

The glass substrate was manufactured by exchanging the sequence of manufacturing process of the glass substrate for magnetic disk as follows: (1) rough lapping process, (2) end surface shaping process, (3) end surface polishing process, (4) precision lapping process (using free abrasive grains), and (5) principal surface polishing process. What differs from the exemplary embodiment is that the surface was ground by replacing the surface grinding process by using fixed abrasive grains by the precision lapping process by using free abrasive grains (7 to 21 μm) smaller than the particle size in the rough lapping process.

[0088] (Comparative example 3: conventional process)

This is the same as the conventional process. That is, the glass substrate

was manufactured in the sequence of manufacturing process of the glass substrate for magnetic disk as follows: (1) rough lapping process, (2) end surface shaping process, (3) precision lapping process (using free abrasive grains), (4) end surface polishing process, and (5) principal surface polishing process. What differs from the exemplary embodiment is that free abrasive grains (7 to 21 μm) were used in the second lapping process after the shaping process, and that the second lapping process was followed by the edge polishing process.

[0089] (Comparative example 4)

The glass substrate was manufactured by exchanging the sequence of manufacturing process of the glass substrate for magnetic disk as follows: (1) rough lapping process, (2) end surface shaping process, (3) surface grinding process (using fixed abrasive grains), (4) end surface polishing process, and (5) principal surface polishing process. Same fixed abrasive grains as in the exemplary embodiment were used. What differs from the exemplary embodiment is that the sequence of the surface grinding process (using fixed abrasive grains) and the end surface polishing process is exchanged.

[0090] The glass substrates manufactured in exemplary embodiment and comparative example 2 to comparative example 4 were observed by a video microscope immediately before the principal surface polishing process, and flaws on the principal surface of the substrate and flaws on the end surface of the substrate were evaluated, and the surface roughness Ra of the glass substrate was measured and evaluated.

[0091] Fig .6 shows evaluation results of exemplary embodiment 2 and comparative example 2 to comparative example 4. The criterion for judging each item is as follows.

<Principal surface flaw>

o: possible to remove by lessened surface wear amount.

x: impossible to remove by lessened surface wear amount.

<End surface flaw>

o: better than present quality.

x: worse than present quality.

<Surface roughness (Ra)>

o: surface polishing amount can be reduced.

□: surface polishing amount is unchanged.

[0092] As shown in Fig. 6, in comparative example 2, flaw was found in the substrate edge portion. Because of precision lapping process by using free abrasive grains executed after the end surface polishing process, free abrasive grains invaded between the carrier and the glass substrate in the precision lapping process, which seems to lead to damage on the edge portion. After surface grinding by free abrasive grains in the precision lapping process, the surface roughness Ra was 0.25 μm.

[0093] In comparative example 3, flaw was found on the principal surface of the glass substrate. It seems to be a remainder of flaw formed in the end surface polishing process when joining the principal surfaces of the glass substrates after the precision lapping process. Same as in comparative example 2, the surface was finally ground by using free abrasive grains, and the surface roughness Ra was 0.25 μm.

[0094] In comparative example 4, flaw was found on the principal surface of the glass substrate. This is also a remainder of flaw formed in the end surface polishing process when joining the principal surfaces of the glass substrates after the precision

lapping process.

[0095] In the glass substrate manufactured in the exemplary embodiment, all inspection items were evaluated to be satisfactory (o). In the exemplary embodiment, the process of joining substrate surfaces mutually is eliminated because it is highly possible to damage the substrate surface in the process after the end surface polishing process, and the principal surface grinding process executed after the process following the end surface polishing process includes a principal surface grinding process by using fixed abrasive grains as a grinding method not damaging the end portion. That is, the principal surface grinding process is executed after the end surface polishing process, and fixed abrasive grains are used in the end surface polishing process, which seems to be main reasons of high evaluation in both the principal surface of the glass substrate and ridge portions of the edges.

[0096] Immediately before the principal surface polishing process, the surface roughness was Ra < 0.1 μm, and the value was suppressed sufficiently lower as compared with Ra = 0.25 μm by using free abrasive grains. Therefore, in the later process of principal surface polishing process, the polishing amount of the substrate principal surface may be saved substantially.

[0097] Exemplary embodiments 1 and 2 of the invention may be combined appropriately. Not limited to exemplary embodiments 1 and 2, the invention may be modified as desired. In exemplary embodiments 1 and 2, the materials, the size, and the processing sequence are only examples, and may be changed and modified within the scope of the invention. Various changes and modifications are possible within a scope not departing from the true spirit of the invention.

CLAIMS

[1] A manufacturing method of glass substrate for magnetic disk having a surface grinding process for processing a mirror-smooth plate glass having a mirror-smooth surface on the principal surface, to a desired flatness and surface roughness by using fixed abrasive grains,

wherein the surface grinding process using the fixed abrasive grains is preceded by a roughening process of roughening the mirror-smooth plate glass surface to a degree capable of being polished by the fixed abrasive grains by a mechanical method or a chemical method.

[2] A manufacturing method of glass substrate for magnetic disk comprising an end surface polishing process of polishing end surfaces of the glass substrate and deburring the end surfaces, and a surface grinding process by using fixed abrasive grains for grinding and processing the principal surface of the glass substrate after the end face polishing to a desired surface roughness and flatness.

[3] The manufacturing method of glass substrate for magnetic disk according to claim 2, further comprising a principal surface polishing process of polishing the principal surface of the glass substrate after the surface grinding process, wherein the grain size of abrasive grains used in the end face polishing surface is larger than the grain size of abrasive grains used in the principal surface polishing process.

[4] The manufacturing method of glass substrate for magnetic disk according to claim 2 or 3, wherein the glass substrate is a mirror-smooth plate glass having a

mirror-smooth surface on the principal surface.

[5] The manufacturing method of glass substrate for magnetic disk according to claim 4, comprising a roughening process of roughening the mirror-smooth plate glass surface to a degree capable of being polished by the fixed abrasive grains by a mechanical method or a chemical method.

[6] The manufacturing method of glass substrate for magnetic disk according to claim 1 or 5, wherein the roughening process is realized by the mechanical method of polishing and processing by using free abrasive grains.

[7] The manufacturing method of glass substrate for magnetic disk according to claim 1 or 5, wherein the roughening process is realized by the chemical method having an etching action by using a chemical solution.

[8] The manufacturing method of glass substrate for magnetic disk according to claim 7, the chemical method having an etching action by using a chemical solution is a frosting process.

[9] The manufacturing method of glass substrate for magnetic disk according to any one of claim 1, and claims 5 to 8, wherein the roughening process is characterized by roughening the mirror-smooth plate glass surface having a mirror-smooth surface roughness of Ra = 0.001 μm or less, to surface roughness of Ra = 0.01 to 0.4 μm.

[10] The manufacturing method of glass substrate for magnetic disk according to any one of claim 1, and claims 5 to 9, wherein the roughening process is characterized by roughening the mirror-smooth plate glass to the condition of B/A < 50, where A is the surface roughness of the glass and B is the average particle size of the fixed abrasive grains.

[11] The manufacturing method of glass substrate for magnetic disk according to any one of claim 1, and claims 4 to 10, wherein the process of processing the mirror-surface plate glass surface by using the fixed abrasive grains is characterized by processing to the surface roughness of Ra = 0.1 μm or less and the flatness of 7 μm or less.

[12] A manufacturing method of magnetic disk for forming at least a magnetic layer on a principal surface of a glass substrate for magnetic disk manufactured by the manufacturing method of glass substrate for magnetic disk of any one of claims 1 to 11.