

DESCRIPTION

[Title of Invention]

GLASS SUBSTRATE FOR INFORMATION RECORDING MEDIUM AND
5 METHOD FOR MANUFACTURING THE SAME

[Technical Field]

[0001] The present invention relates to a glass substrate for an information recording medium and a method for manufacturing the same.

10 [Background Art]

[0002] Conventionally, an aluminum substrate or a glass substrate has been used in an information recording medium (magnetic-disk information medium) used in a computer or the like. A magnetic thin film layer is formed on the substrate and magnetized with a magnetic head, and thus information is
15 recorded in the magnetic thin film layer.

[0003] In recent years, recording density has been increasingly improved in hard disk drive (HDD) devices. Due to the improvement of recording density, a gap (flying height) between an information recording medium (medium) and a head that reads/writes records while flying above the information recording
20 medium has decreased to about several nanometers.

[0004] As the flying height decreases, problems such as a read error and/or a write error when accessing data recorded in a medium, and a head crash in which the magnetic head collides with the surface of a medium in the case where an information recording medium is used in a hard disk drive device are
25 more likely to occur. In order to suppress these problems, higher surface smoothness of a glass substrate for an information recording medium has been pursued to further reduce the size of defects on the surface of the substrate that are acceptable in an information recording medium, and various manufacturing methods have been devised to suppress foreign matter adhering
30 to the surface of the glass substrate and waviness in the surface of the glass

substrate.

[0005] On the other hand, in recent years, the storage capacity of an HDD has further increased. Nowadays, a 2.5-inch recording medium has been developed in which the recording density allows a storage capacity of 500 GB (250 GB on one side) and a surface recording density of equal to or greater than 600 Gbit per square inch. It was found that even when a glass substrate having a very high surface smoothness is used for such a recording medium having a high recording density, a read error and/or a write error sometimes occur when accessing data. Analysis of the cause of the errors revealed that the errors were not conventional errors caused by a head crash.

[0006] To address the above-described problems, a close investigation of the surface state and the like of a manufactured glass substrate was made, but defects causing a read error and/or a write error were not observed, and no specific solution was found. However, as a result of the close investigation, it was found that the signal-to-noise ratio of magnetic signals varied after a magnetic layer was provided on the manufactured glass substrate and that this possibly caused a read error and/or a write error. In the present invention, such variation in the signal-to-noise ratio of magnetic signals is also referred to as "reduction of electromagnetic conversion characteristics (SNR)".

[0007] As a result of further research on a cause of such variation of the signal-to-noise ratio of magnetic signals, the following was revealed. Generally, a glass substrate for an information recording medium is packed and sealed after being manufactured. Then, after being transported, the glass substrate is unpacked and subjected to a process for forming a magnetic layer. At this time, due to the difference in conditions during packing, transportation and unpacking, the surface state of the glass substrate may become uneven or a small quantity of particles may adhere thereto, and therefore, the glass substrate is cleaned to make the surface state uniform using a detergent that has relatively high cleaning performance such as an alkaline solution, and, in some cases, has the characteristic of slightly dissolving the surface (see JP

2006-127624A (Patent Literature 1)). The above-described variation in the signal-to-noise ratio of magnetic signals is caused by the impairment of a stable state of the glass surface when the glass substrate is cleaned just before the magnetic layer is formed, and it is clear that this was the reason why the cause
5 could not be identified even when the glass substrate itself was examined after being manufactured.

[Citation List]

[Patent Literature]

[0008] [PLT 1]: JP 2006-127624A

10 [Summary of Invention]

[Technical Problem]

[0009] As described above, with a glass substrate used in a hard disk drive device having a recording density equal to or greater than 600 Gbit per square inch, there was a problem in that the electromagnetic conversion
15 characteristics (SNR) of the information recording medium decreased, despite the substrate itself having no problems in terms of smoothness and cleanliness.

[0010] As a result of further research, the inventors of the present invention found that the electromagnetic conversion characteristics (SNR) of a glass substrate in which Ra (average surface roughness) changed significantly before
20 and after the above-described alkali cleaning step decreased markedly.

[0011] A large change in Ra of a glass substrate after the alkali cleaning step causes variation in the orientation of the magnetic thin film layer (magnetic layer). It was found that as a result, the signal-to-noise ratio (S/N ratio: SNR) decreased in the information recording medium obtained by forming a magnetic
25 thin film layer on the glass substrate whose Ra had changed significantly.

[0012] The present invention was achieved in light of the aforementioned circumstances, and it is an object thereof to provide a glass substrate for an information recording medium in which the signal-to-noise ratio (S/N ratio) is not reduced even when the glass substrate is used in an information recording
30 medium in which the magnetic recording surface has a very high recording

density equal to or greater than 600 Gbit per square inch, for example, and to provide a method for manufacturing the glass substrate for an information recording medium.

[Solution to Problem]

5 [0013] A glass substrate for an information recording medium according to the present invention is a glass substrate for an information recording medium to be used in an information recording medium which has a magnetic recording layer formed on a main surface of the glass substrate and in which a recording density of a magnetic recording surface is equal to or greater than 600 Gbit per
10 square inch, wherein an average value of change values of Ra of a surface of the glass substrate for an information recording medium before and after being subjected to a first alkali treatment in which the glass substrate for an information recording medium is immersed in a sodium hydroxide solution at pH 11 at 40°C for 30 minutes is 0.50 Å or less, and an average value of change
15 values of Ra of a surface of the glass substrate for an information recording medium before and after being subjected to a second alkali treatment in which the glass substrate for an information recording medium is immersed in a sodium hydroxide solution at pH 12 at 25°C for 2.5 hours is 2.00 Å or less.

[0014] In the glass substrate for an information recording medium according to
20 another aspect, the average value of change values of Ra before and after the first alkali treatment is 0.30 Å or less, and the average value of change values of Ra before and after the second alkali treatment is 1.50 Å or less.

[0015] In another aspect, Ra of the surface of the glass substrate for an information recording medium when measured using an atomic force
25 microscope is 1.7 Å to 2.3 Å in measurement of a region of 1 μm^2 and 1.4 Å to 1.7 Å in measurement of a region of 10 μm^2 .

[0016] A method for manufacturing the glass substrate for an information recording medium according to the present invention is a method for manufacturing the glass substrate for an information recording medium
30 according to any one of the above-described aspects, and the method includes a

polishing step of polishing main surfaces of a circular glass member, a treatment bringing the polished circular glass member into contact with hydrogen-rich water of 0.1 to 1.4 ppm for 1 to 10 minutes, an alkaline solution at pH 10.0 to 11.0 for 5 to 20 minutes and an organic acid of 0.05 to 0.5% for 5 to 20 minutes in the stated order after the polishing step, and a final cleaning step.

[0017] Another method for manufacturing the glass substrate for an information recording medium according to the present invention is a method for manufacturing the glass substrate for an information recording medium according to any one of the above-described aspects, and the method includes a polishing step of polishing main surfaces of a circular glass member, a treatment bringing the polished circular glass member into contact with an alkaline solution at pH 10.0 to 11.0 for 5 to 20 minutes and an organic acid of 0.05 to 0.5% for 5 to 20 minutes in the stated order after the polishing step, and a final cleaning step.

[0018] Another method for manufacturing the glass substrate for an information recording medium according to the present invention is a method for manufacturing the glass substrate for an information recording medium according to any one of the above-described aspects, and the method includes a polishing step of polishing main surfaces of a circular glass member, a treatment of bringing the polished circular glass member into contact with hydrogen-rich water of 1.5 ppm for 3 minutes and an alkaline solution at pH 10.0 to 11.0 for 5 to 20 minutes in the stated order after the polishing step, and a final cleaning step.

[Advantageous Effects of the Invention]

[0019] With the present invention, it is possible to provide a glass substrate for an information recording medium in which the signal-to-noise ratio (S/N ratio) is not reduced even when the glass substrate is used in an information recording medium in which the magnetic recording surface has a very high recording density equal to or greater than 600 Gbit per square inch, for

example, and to provide a method for manufacturing the glass substrate for an information recording medium.

[Brief Description of Drawings]

5 [0020] FIG. 1 is a perspective view of a glass substrate for an information recording medium according to an embodiment.

FIG. 2 is a perspective view of an information recording medium according to the embodiment.

FIG. 3 is a flowchart illustrating a method for manufacturing the information recording medium according to the embodiment.

10 FIG. 4 is a drawing showing evaluation results of the glass substrates for an information recording medium according to Working Examples 1 to 3 and Comparative Examples 1 and 2.

[Description of Embodiments]

15 [0021] Hereinafter, an embodiment and examples will be described. Identical or equivalent parts are denoted by identical reference numerals and descriptions thereof may be omitted. When numbers, amounts, and so on are referred to in the following embodiment and examples, the scope of the present invention is not necessarily limited to those numbers, amounts, and so on, unless explicitly mentioned otherwise. Each component of the following
20 embodiment is not necessarily essential for the present invention unless explicitly mentioned otherwise.

[0022] (Configuration of information recording medium 1)

Configurations of a glass substrate for an information recording medium 1G and an information recording medium 1 will be described with
25 reference to FIGS. 1 and 2. FIG. 1 is a perspective view of the glass substrate for an information recording medium 1G, and FIG. 2 is a perspective view of the information recording medium.

[0023] As shown in FIG. 1, the glass substrate for an information recording medium 1G (referred to as "glass substrate 1G" hereinafter) to be used in the
30 information recording medium 1 has an annular disk shape in which a hole 11

is formed at the center. The glass substrate 1G has an outer circumferential end surface 12, an inner circumferential end surface 13, a front main surface 14, and a back main surface 15. The glass substrate 1G is made of amorphous glass or the like and has an outer diameter of about 65 mm, an inner diameter of about 20 mm, a thickness of about 0.8 mm, and a surface roughness of about 2.0 Å or less, for example.

[0024] The inch size of the glass substrate 1G is not particularly limited, and various glass substrates 1G including 0.8-inch, 1.0-inch, 1.8-inch, 2.5-inch, and 3.5-inch glass substrates may be manufactured as a disk for an information recording medium.

[0025] The thickness of the glass substrate 1G is preferably 0.30 to 2.2 mm because it is effective against breakage of the glass substrate 1G due to drop impact. The thickness of the glass substrate 1G here means an average value of the values measured at several arbitrary points on the substrate that have point symmetry.

[0026] As shown in FIG. 2, in the information recording medium 1, a magnetic thin film layer 23 is formed on the above-described front main surface 14 of the glass substrate 1G. In the drawing, the magnetic thin film layer 23 is formed on only the front main surface 14, but it is also possible to form a magnetic thin film layer 23 on the back main surface 15.

[0027] Conventionally known methods can be used as a method for forming the magnetic thin film layer 23. Examples thereof include a formation method that involves spin-coating a thermosetting resin in which magnetic particles are dispersed on the glass substrate 1G, a formation method that uses sputtering, and a formation method that uses electroless plating.

[0028] The thickness of the film obtained by the spin coat method is about 0.3 to 1.2 μm, the thickness of the film obtained by the sputtering method is about 0.01 to 0.08 μm, and the thickness of the film obtained by the electroless plating method is about 0.01 to 0.1 μm. From the viewpoint of making the film thinner and denser, it is preferable to form the film by the sputtering method or

the electroless plating method.

[0029] The magnetic materials used for the magnetic thin film layer 23 are not particularly limited, and conventionally known materials can be used. In order to provide high adhesion strength, it is preferable to use a Co-based alloy that contains Co, which has high crystal anisotropy, as a main component and to which Ni and Cr are added to adjust the residual magnetic flux density, and the like. In recent years, FePt-based materials have been used as magnetic materials that are preferable for thermally assisted recording.

[0030] In order to allow the magnetic head to slide smoothly, the surface of the magnetic thin film layer 23 may be thinly coated with a lubricant. One example of the lubricant is a lubricant obtained by diluting perfluoropolyether (PFPE), which is a liquid lubricant, with a Freon-based solvent or the like.

[0031] A base layer and a protecting layer may be provided as needed. The base layer in the information recording medium 1 is selected according to the magnetic film. For example, at least one selected from non-magnetic metals such as Cr, Mo, Ta, Ti, W, V, B, Al, and Ni can be used as a material for the base layer.

[0032] The base layer is not limited to a single layer, and may have a multilayer structure in which the same type or different types of layers are laminated. For example, the base layer may be a multilayer base layer made of Cr/Cr, Cr/CrMo, Cr/CrV, NiAl/Cr, NiAl/CrMo, NiAl/CrV, or the like.

[0033] Examples of the protecting layer for preventing wear and corrosion of the magnetic thin film layer 23 include a Cr layer, a Cr alloy layer, a carbon layer, a hydrogenated carbon layer, a zirconia layer, and a silica layer. Similarly to the base layer, the magnetic film, and the like, the protecting layer can be continuously formed using an inline-type sputtering device. The protecting layer may be a single layer or have a multilayer configuration constituted by the same type or different types of layers.

[0034] Another protecting layer may be formed on the above protecting layer or instead of the above protecting layer. For example, instead of the above

protecting layer, a silicon oxide (SiO_2) layer may be formed by applying a solution obtained by diluting tetraalkoxysilane with an alcohol-based solvent and dispersing colloidal silica minute particles therein on a Cr layer, and by firing the Cr layer.

5 [0035] As described above, a glass substrate 1G for an information recording medium is packed and sealed in a packing material after being manufactured. Then, after being distributed, the glass substrate is taken out from the packing material and is provided with a magnetic thin film layer 23 and the like. In order to remove minute particles that have attached thereto during packing
10 and/or transportation and to eliminate the unevenness of the surface state due to the difference in conditions, the glass substrate is cleaned with an alkaline solution or the like just before the magnetic thin film layer 23 and the like are provided.

[0036] Even when such an alkali cleaning treatment is performed, it is possible
15 to sufficiently suppress a reduction in the signal-to-noise ratio (S/N ratio) in the case of a glass substrate for an information recording medium with respect to which the average value of the change values of Ra of the surface of the glass substrate for an information recording medium before and after being subjected to a first alkali treatment in which the glass substrate for an information
20 recording medium is immersed in a sodium hydroxide solution at pH 11 at 40°C for 30 minutes is 0.50 Å or less, and with respect to which the average value of the change values of Ra of the surface of the glass substrate for an information recording medium before and after being subjected to a second alkali treatment in which the glass substrate for an information recording medium is immersed
25 in a sodium hydroxide solution at pH 12 at 25°C for 2.5 hours is 2.00 Å or less, even when the glass substrate is used in an information recording medium in which the magnetic recording surface has a very high recording density of equal to or greater than 600 Gbit per square inch, for example.

[0037] (Steps of manufacturing glass substrate 1G)

30 Next, a method for manufacturing the glass substrate 1G and the

information recording medium 1 according to this embodiment will be described with reference to FIG. 3. FIG. 3 is a flowchart illustrating a method for manufacturing the glass substrate 1G and the information recording medium 1.

5 [0038] First, in "a glass melting step" of step 10 (abbreviated as "S10" hereinafter; the same applies to step 11 onward), a glass material constituting the glass substrate was melted.

[0039] In "a press molding step" of S11, a glass substrate was manufactured by pressing the molten glass material using an upper mold and a lower mold.

10 The glass used had the same composition as that of common aluminosilicate glass. The method for manufacturing a glass substrate is not limited to molding, and cutting out from plate glass, which is a known method, or the like may be performed. Also, the glass composition is not limited to the above composition.

15 [0040] In "a first lapping step" of S12, two main surfaces was lapped. This first lapping step was performed using a double-side lapping device utilizing a planetary gear mechanism. Specifically, lapping was performed by pressing lapping surface plates onto the two surfaces of the glass substrate from the upper and lower sides, supplying a grinding liquid to the main surfaces of the glass substrate, and relatively moving them. The glass substrate having

20 substantially flat main surfaces was obtained by this lapping processing.

[0041] In "a coring step" of S13, a hole was formed at the center portion of the glass substrate using a tubular diamond drill to produce an annular glass substrate. The inner circumferential end surface and outer circumferential

25 end surface of the glass substrate were ground using a diamond grindstone, and predetermined chamfering was performed.

[0042] In "a second lapping step" of S14, the two main surfaces of the glass substrate were lapped as in the first lapping step (S12). By performing this second lapping step, it is possible to eliminate in advance the unevenness

30 formed on the main surfaces by the coring processing and the end surface

processing in the previous step. As a result, it is possible to reduce the time required for polishing the main surfaces in the later steps.

[0043] In "an outer circumference polishing step" of S15, mirror polishing was performed on the outer circumferential end surface of the glass substrate by performing brushing. In this case, a slurry containing common cerium oxide abrasive grains was used as abrasive grains.

[0044] In "a first polishing step" of S16, the main surfaces were polished. This first polishing step is performed mainly to eliminate scratches and/or warping that remain in the main surfaces in the above-described first and second lapping steps (S12 and S14). In this first polishing step, the main surfaces were polished using a double-side polishing device having a planetary gear mechanism. Common cerium oxide abrasive grains were used as a polishing agent.

[0045] In "a chemical strengthening step" of S17, surface strengthening layers were formed on the main surfaces of the glass substrate 1G. Specifically, chemical strengthening was performed by bringing the glass substrate 1G into contact with a mixed solution of potassium nitrate (70%) and sodium nitrate (30%) that had been heated to 300°C, for about 30 minutes. As a result, lithium ions and sodium ions of the inner circumferential end surface and the outer circumferential end surface of the glass substrate were respectively substituted for sodium ions and potassium ions in the chemical strengthening solution and a compressive stress layer was formed, thus chemically strengthening the main surfaces and the end surfaces of the glass substrate.

[0046] In "a second polishing step" of S18, a main surface polishing step was performed. This second polishing step is performed to mirror-finish the main surfaces by eliminating any remaining small defects or the like on the main surfaces and to finish the main surfaces to a desired smoothness by eliminating warping. In this second polishing step, polishing was performed using a double-side polishing device having a planetary gear mechanism. Colloidal silica having an average particle size of about 20 nm was used as a polishing

agent in order to obtain smooth surfaces.

[0047] After "the second polishing step" is performed, a pre-treatment step of S19 of suppressing the change in Ra (average surface roughness) of the surface of the glass substrate due to the alkali treatment is performed in order to enhance the stability of the glass substrate to the alkali cleaning treatment that is performed just before the glass substrate for an information recording medium is provided with the magnetic thin film layer and to suppress the reduction of electromagnetic conversion characteristics (SNR) of the information recording medium that has been coated with the magnetic thin film layer.

[0048] Specifically, the pre-treatment step is performed such that when the first alkali treatment in which the glass substrate for an information recording medium is immersed in a sodium hydroxide solution at pH 11 at 40°C for 30 minutes is performed, the average value of the change values of Ra of the surface of the glass substrate for an information recording medium before and after the first alkali treatment is 0.50 Å or less, and when the second alkali treatment in which the glass substrate for an information recording medium is immersed in a sodium hydroxide solution at pH 12 at 25°C for 2.5 hours is performed, the average value of the change values of Ra of the surface of the glass substrate for an information recording medium before and after the second alkali treatment is 2.00 Å or less.

[0049] In the pre-treatment step, a step of bringing the glass substrate into contact with hydrogen-rich water of 0.1 to 1.4 ppm for 1 to 10 minutes and a treatment of bringing the glass substrate into contact with an organic acid of 0.05 to 0.5% for 5 to 20 minutes are performed in combination with the step of bringing the glass substrate into contact with an alkaline solution at pH 10.0 to 11.0 for 5 to 20 minutes as appropriate, thus making it possible to adjust the change values of Ra after the alkali treatment as described above.

[0050] In the step of bringing the glass substrate into contact with the alkaline solution, components that exist on the surface of the glass substrate and are

eluted by the alkaline solution are removed in advance, thus making it possible to suppress the change in Ra due to the alkali treatment. As a result, even when the alkali cleaning is performed just before the magnetic thin film layer is provided, it is possible to obtain the effect of suppressing a reduction in the signal-to-noise ratio (S/N ratio).

[0051] However, if the pH of the alkaline solution is increased or the contact time is extended in this case, the elution from the surface of the glass substrate becomes excessive, Ra is increased, and it becomes difficult to maintain the smoothness necessary for the glass substrate for an information recording medium. Accordingly, it is difficult to sufficiently suppress the change in Ra due to the alkali treatment by performing only the step of bringing the glass substrate into contact with the alkaline solution, and therefore, it is necessary to perform this step in combination with another stabilizing step. A sodium hydroxide solution or the like is preferably used as the alkaline solution.

[0052] Here, the step of bringing the glass substrate into contact with hydrogen-rich water serves to reduce the surface charge of the glass substrate. Accordingly, it is possible to suppress the reduction of Ra due to the alkali treatment and enhance the stability of the surface of the glass substrate to the alkali treatment.

[0053] In the step of bringing the glass substrate into contact with an organic acid, the effect of smoothing Ra that has been deteriorated by bringing the glass substrate into contact with an alkaline solution can be obtained without impairing the stability to the alkali treatment. On the other hand, if the concentration of the organic acid is excessively increased or the glass substrate is caused to be in contact with the organic acid for a long period of time, Ra is deteriorated. Preferable examples of the organic acid include ascorbic acid and sulfamic acid. Ascorbic acid is particularly preferable.

[0054] "Contact" with a solution in the present invention may be achieved by showering the solution on the surface of the glass substrate or by immersing the glass substrate in the solution, and there is no limitation as long as the

state in which the glass substrate is in contact with the solution continues for a predetermined period of time.

[0055] Then, in "a final cleaning step" of S20, final cleaning of the main surfaces and the end surfaces of the glass substrate is performed. Thus, attached matter remaining on the glass substrate is removed. The final cleaning step is performed as the last step of the steps of manufacturing the glass substrate and includes a drying step as appropriate.

[0056] In this embodiment, the glass substrate for an information recording medium refers to a glass substrate that has finished undergoing the final cleaning step, and this glass substrate is generally sealed in a packing material and distributed.

[0057] In this embodiment, the change in Ra when a specific alkali treatment is performed on the glass substrate is used as an index for sufficiently suppressing a reduction in the signal-to-noise ratio (S/N ratio) of a magnetic recording medium after a magnetic thin film layer is provided thereon due to the alkali cleaning treatment that is performed just before the magnetic thin film layer is provided on the glass substrate for an information recording medium to form the magnetic recording medium.

[0058] Specifically, the condition for manufacturing a glass substrate is determined by adjusting the foregoing pre-treatment step so as to satisfy the range of change in Ra due to the alkali treatment in this embodiment. This makes it possible to reduce variation in the orientation of a magnetic thin film layer (magnetic layer) that is caused by the deterioration of the surface state due to the alkali cleaning step performed before the glass substrate is coated with the magnetic thin film layer, and to provide a glass substrate for an information recording medium with which a reduction of the signal-to-noise ratio (S/N ratio) can be sufficiently suppressed, even when the information recording medium is produced by providing a magnetic thin film layer after performing an alkali cleaning treatment.

[0059] The surface roughness of the glass substrate is measured using an

atomic force microscope (AFM), for example. Ra of the surface of the glass substrate is obtained by measuring a square region of $1\ \mu\text{m} \times 1\ \mu\text{m}$ on the glass substrate. The average value of Ra is obtained by averaging the values obtained by measuring three or more square regions of $1\ \mu\text{m} \times 1\ \mu\text{m}$ on the glass substrate.

[0060] A change value of Ra (difference of Ra values) can be obtained by measuring Ra of the surface of the glass substrate before and after the alkali treatment, and the average value of the change values of Ra is obtained by using the number of measurement points.

[0061] The method for manufacturing a glass substrate according to this embodiment is configured as described above. It is possible to manufacture the glass substrate 1G shown in FIG. 1 by this method for manufacturing a glass substrate. Thereafter, the information recording medium 1 shown in FIG. 2 is manufactured by using the glass substrate 1G obtained in this manner.

[0062] Moreover, in a magnetic thin film layer forming step in the manufacture of the information recording medium, an adhesive layer made of Cr alloy, a soft magnetic layer made of CoFeZr alloy, an orientation-controlling base layer made of Ru, a perpendicular magnetic recording layer made of CoCrPt alloy, a C-based protecting layer, and an F-based lubricating layer are laminated in a sequential manner on the two main surfaces of the glass substrate 1G after cleaning the glass substrate 1G obtained through the above-described steps, and thus the information recording medium of a perpendicular magnetic recording type is manufactured. This configuration is one example of the configuration of a perpendicular magnetic recording medium, and the magnetic layer and the like may be configured to produce a longitudinal information recording medium. Thereafter, the information recording medium 1 is completed by performing a heat treatment step and the like later.

[0063] (Examples)

Glass substrates 1G were manufactured by performing treatment shown in Working Examples 1 to 3 as the pre-treatment step (S19) of suppressing changes in Ra (average surface roughness) of the surface of the glass substrate 1 after performing "the second polishing step" in the method for manufacturing a glass substrate shown in the above-described embodiment. The magnetic thin film layer forming step was performed on the manufactured glass substrates 1G after performing the alkali cleaning, and thus information recording media were manufactured. Similarly, treatment shown in Comparative Examples 1 and 2 was also performed.

5 [0064] (Working Example 1)

In Working Example 1, after "the second polishing step" was performed, the glass substrate was rinsed by being showered with hydrogen-rich water of 1.5 ppm for 3 minutes. Thereafter, the glass substrate was brought into contact with a sodium hydroxide solution at pH 10.5 for 5 minutes, and then was brought into contact with 0.1% ascorbic acid for 15 minutes. Then, the final cleaning was performed on the glass substrate using pure water.

15 [0065] (Working Example 2)

In Working Example 2, after "the second polishing step" was performed, the glass substrate was rinsed by being showered with pure water. Thereafter, the glass substrate 1G was brought into contact with a sodium hydroxide solution at pH 10.5 for 5 minutes, and then was brought into contact with 0.1% ascorbic acid for 15 minutes. Then, the final cleaning was performed on the glass substrate using pure water.

20 [0066] (Working Example 3)

In Working Example 3, after "the second polishing step" was performed, the glass substrate was rinsed by being showered with hydrogen-rich water of 1.5 ppm for 3 minutes. Thereafter, the glass substrate was brought into contact with a sodium hydroxide solution at pH 10.5 for 5 minutes, and then the final cleaning was performed on the glass substrate using pure water.

25 [0067] (Comparative Example 1)

In Comparative Example 1, after "the second polishing step" was performed, the glass substrate was brought into contact with 0.1% ascorbic acid for 15 minutes. Then, the glass substrate was cleaned using pure water.

[0068] (Comparative Example 2)

5 In Comparative Example 2, after "the second polishing step" was performed, the glass substrate 1G was cleaned using pure water.

[0069] <Measurement of change in Ra due to alkali treatment>

Ten glass substrates 1G were extracted from one hundred glass substrates 1G obtained by realizing each of Working Examples 1 to 3 and
10 Comparative Examples 1 and 2, and Ra of three square regions of $1\ \mu\text{m} \times 1\ \mu\text{m}$ of each glass substrate was measured using an AFM.

[0070] As an alkali treatment step under the first condition, alkali cleaning using a sodium hydroxide solution at pH 11 at 40°C was performed on the glass substrate for 30 minutes. Then, Ra of three square regions of $1\ \mu\text{m} \times 1\ \mu\text{m}$ of
15 each glass substrate after the alkali treatment step was measured using an AFM, the three square regions being the same as those in the measurement of Ra before the alkali treatment.

[0071] As a second alkali treatment step, second alkali cleaning using a sodium hydroxide solution at pH 12 at 25°C was performed on the glass
20 substrate for 2.5 hours. Then, Ra of three square regions of $1\ \mu\text{m} \times 1\ \mu\text{m}$ of each glass substrate after the alkali treatment step was measured using an AFM, the three square regions being the same as those in the measurement of Ra's before the alkali treatment.

[0072] The difference between the measured Ra values before the alkali
25 treatment and the measured Ra values after the alkali treatment at each measurement point was obtained, the average value thereof was obtained, and then the average value of the ten samples was taken as the average value of change values of Ra of each example.

[0073] Table 1 shows the average values of change values of Ra under the
30 conditions of Working Examples 1 to 3 and Comparative Examples 1 and 2.

[0074] Since one hundred glass substrates 1G per batch were manufactured, and there was little variation in the evaluation of glass substrates in the same batch, the glass substrates were evaluated as shown above.

[0075] <Evaluation of electromagnetic conversion characteristics of information recording medium>

Twenty arbitrary glass substrates 1G were extracted from the ninety samples of each of Working Examples 1 to 3 and Comparative Examples 1 and 2 that were not used in the alkali treatment test, and the electromagnetic conversion characteristics thereof were evaluated. At this time, in order to simulate the normal distribution state, the manufactured glass substrates were sealed in a packing material, and, after being kept for one day, were unpacked and used.

[0076] Ra of the twenty glass substrates of each of Working Examples 1 to 3 and Comparative Examples 1 and 2 was measured. Specifically, as a measurement in the region of $1\text{ }\mu\text{m}^2$, Ra of three square regions of $1\text{ }\mu\text{m} \times 1\text{ }\mu\text{m}$ of each glass substrate were measured using an AFM, and the average values were obtained. As a measurement in the region of $100\text{ }\mu\text{m}^2$, Ra of three square regions of $10\text{ }\mu\text{m} \times 10\text{ }\mu\text{m}$ was measured, and the average values were obtained.

[0077] Before the magnetic thin film layer forming step was performed, the glass substrates were immersed in a sodium hydroxide solution at pH 11.5 at 30°C in a water flow type cleaning tank for 60 minutes as the alkali cleaning treatment.

[0078] When the electromagnetic conversion characteristics were evaluated, a magnetic thin film layer was formed on each of the twenty glass substrates 1G by performing the above-described magnetic thin film layer forming step to produce an information recording medium, and then the electromagnetic conversion characteristics were evaluated. Specifically, SNR values were compared with the SNR value of a standard information recording medium.

[0079] The electromagnetic conversion characteristics of the information recording medium were evaluated by investigating the recording and

reproducing characteristics when using a magnetic head. Specifically, the characteristics were investigated by recording signals with recording density changed by changing recording frequencies, and by reading the reproduction output of these signals. The recording density of the information recording medium was set to 650 Gbit/inch².

[0080] A merge type head for perpendicular recording in which a single magnetic pole head for perpendicular recording (for recording) and a GMR head (for reproduction) were integrated was used as the magnetic head. An SNR value of -0.1 db or more was evaluated as "A", an SNR value of -0.20 db or more to -0.11 or less was evaluated as "B", an SNR value of -0.30 db or more to -0.21 or less was evaluated as "C", and an SNR value of -0.31 or less was evaluated as "D". The SNR value here refers to the difference from a predetermined standard value.

[0081] In order to confirm that errors were caused by the electromagnetic conversion characteristics, the cleanliness of the glass substrate 1G before the above-described alkali cleaning treatment was checked by a defect test using an optical surface analysis device set to have a predetermined detection sensitivity, such as an optical surface analyzer (OSA). The counted value of defects measured by the optical surface analysis device refers to the number of defects such as attached matter and depressions per information recording medium. The larger the counted value is, the poorer the cleanliness of the surface is.

[0082] FIG. 4 shows the evaluation results of Working Examples 1 to 3 and Comparative Examples 1 and 2. Specifically, FIG. 4 shows SNR values (db) of the information recording media of Working Examples 1 to 3 and Comparative Examples 1 and 2 with respect to that of the standard information recording medium, (iv) OSA count values of Working Examples 1 to 3 and Comparative Examples 1 and 2, and (v) evaluations of Working Examples 1 to 3 and Comparative Examples 1 and 2.

[0083] In Working Example 1, (i) the change value of R_a before and after the first alkali treatment was " 0.25 (Å)", and (ii) the change value of R_a before and

after the second alkali treatment was "1.30 (Å)", the SNR value (db) of the information recording medium manufactured using the glass substrate that was manufactured under the conditions of Working Example 1 was "0.21 (db)", and (iv) the OSA count value was "7". As a result, Working Example 1 was
5 evaluated as "A".

[0084] In Working Example 2, (i) the change value of Ra before and after the first alkali treatment was "0.37 (Å)", and (ii) the change value of Ra before and after the second alkali treatment was "1.40 (Å)", the SNR value (db) of the information recording medium manufactured using the glass substrate that
10 was manufactured under the conditions of Working Example 2 was "−0.12 (db)", and (iv) the OSA count value was "10". As a result, Working Example 2 was evaluated as "B".

[0085] In Working Example 3, (i) the change value of Ra before and after the first alkali treatment was "0.45 (Å)", and (ii) the change value of Ra before and
15 after the second alkali treatment was "1.98 (Å)", the SNR value (db) of the information recording medium manufactured using the glass substrate that was manufactured under the conditions of Working Example 3 was "−0.23 (db)", and (iv) the OSA count value was "8". As a result, Working Example 3 was evaluated as "C".

20 [0086] In Comparative Example 1, (i) the change value of Ra before and after the first alkali treatment was "0.53 (Å)", and (ii) the change value of Ra before and after the second alkali treatment was "2.11 (Å)", the SNR value (db) of the information recording medium manufactured using the glass substrate that was manufactured under the condition of Comparative Example 1 was "−0.39
25 (db)", and (iv) the OSA count value was "9". As a result, Comparative Example 1 was evaluated as "D".

[0087] In Comparative Example 2, (i) the change value of Ra before and after the first alkali treatment was "0.64 (Å)", and (ii) the change value of Ra before and after the second alkali treatment was "2.53 (Å)", the SNR value (db) of the
30 information recording medium manufactured using the glass substrate that

was manufactured under the condition of Comparative Example 2 was "-0.55 (db)", and (iv) the OSA count value was "11". As a result, Comparative Example 2 was evaluated as "D".

[0088] If an information recording medium is evaluated as "A" to "C", it is possible to secure the reliability of the information recording medium. Accordingly, based on the results from Working Examples 1 to 3 and Comparative Examples 1 and 2, it is preferable to manufacture the glass substrate under such conditions that the average value of change values of Ra of the surface of the glass substrate before and after the first alkali treatment is 0.50 Å or less and the average value of change values of Ra of the surface of the glass substrate before and after the second alkali treatment is 2.00 Å or less. Furthermore, from the viewpoint of the evaluation as "A" and "B", it is preferable to use the glass substrate manufactured under such conditions that the average value of change values of Ra of the surface of the glass substrate before and after the first alkali treatment is 0.30 Å or less and the average value of change values of Ra of the surface of the glass substrate for an information recording medium before and after the second alkali treatment is 1.50 Å or less.

[0089] In the working examples and comparative examples, the values measured by an OSA, which represent the cleanliness of the surface of the glass substrate, did not significantly differ from each other, and thus it was confirmed that the change values of Ra affected the SNR characteristics.

[0090] With the information recording medium using the glass substrate 1G within the above-described range, it is possible to provide a glass substrate for an information recording medium in which the signal-to-noise ratio (S/N ratio) is not reduced even when the glass substrate is used for a hard disk drive device having a recording density of equal to or greater than 600 Gbit/inch².

[0091] While the embodiment and examples of the present invention has been described above, the disclosed embodiment and examples are to be understood as being exemplary in all respects and in no way limiting. The scope of the

present invention is defined by the scope of the appended claims, and all changes that fall within the same essential spirit as the scope of the claims are intended to be included therein.

[List of Reference Numerals]

- 5 [0092] 1: Information recording medium, 1G: Glass substrate for an information recording medium, 11: Hole, 12: Outer circumferential end surface, 13: Inner circumferential end surface, 14: Front main surface, 15: Back main surface, 23: Magnetic thin film layer.

CLAIMS

1. A glass substrate for an information recording medium to be used in an information recording medium which has a magnetic recording layer formed on
5 a main surface of the glass substrate and in which a recording density of a magnetic recording surface is equal to or greater than 600 Gbit per square inch,
wherein an average value of change values of Ra of a surface of the glass substrate for an information recording medium before and after being subjected to a first alkali treatment in which the glass substrate for an
10 information recording medium is immersed in a sodium hydroxide solution at pH 11 at 40°C for 30 minutes is 0.50 Å or less, and
an average value of change values of Ra of a surface of the glass substrate for an information recording medium before and after being subjected to a second alkali treatment in which the glass substrate for an information
15 recording medium is immersed in a sodium hydroxide solution at pH 12 at 25°C for 2.5 hours is 2.00 Å or less.
2. The glass substrate for an information recording medium according to claim 1,
20 wherein the average value of change values of Ra before and after the first alkali treatment is 0.30 Å or less, and
the average value of change values of Ra before and after the second alkali treatment is 1.50 Å or less.
- 25 3. The glass substrate for an information recording medium according to claim 1 or 2,
wherein Ra of the surface of the glass substrate for an information recording medium when measured using an atomic force microscope is 1.7 Å to 2.3 Å in measurement of a region of 1 μm^2 and 1.4 Å to 1.7 Å in measurement of
30 a region of 10 μm^2 .

4. A method for manufacturing a glass substrate for an information recording medium according to any one of claims 1 to 3, comprising:

a polishing step of polishing main surfaces of a circular glass member;

5 a treatment bringing the polished circular glass member into contact with hydrogen-rich water of 0.1 to 1.4 ppm for 1 to 10 minutes, an alkaline solution at pH 10.0 to 11.0 for 5 to 20 minutes and an organic acid of 0.05 to 0.5% for 5 to 20 minutes in the stated order after the polishing step; and
a final cleaning step.

10

5. A method for manufacturing a glass substrate for an information recording medium according to any one of claims 1 to 3, comprising:

a polishing step of polishing main surfaces of a circular glass member;

a treatment bringing the polished circular glass member into contact
15 with an alkaline solution at pH 10.0 to 11.0 for 5 to 20 minutes and an organic acid of 0.05 to 0.5% for 5 to 20 minutes in the stated order after the polishing step; and
a final cleaning step.

20 6. A method for manufacturing a glass substrate for an information recording medium according to any one of claims 1 to 3, comprising:

a polishing step of polishing main surfaces of a circular glass member;

a treatment of bringing the polished circular glass member into contact
with hydrogen-rich water of 1.5 ppm for 3 minutes and an alkaline solution at
25 pH 10.0 to 11.0 for 5 to 20 minutes in the stated order after the polishing step;
and
a final cleaning step.