

DESCRIPTION

TITLE OF THE INVENTION:

GLASS SUBSTRATE FOR MAGNETIC RECORDING MEDIUM AND MAGNETIC
5 RECORDING MEDIUM

TECHNICAL FIELD

[0001]

The present invention relates to a glass substrate for a magnetic recording
10 medium and a magnetic recording medium.

BACKGROUND ART

[0002]

In magnetic recording devices, a magnetic layer etc. is formed on a substrate for
15 a magnetic recording medium, and information can be recorded by using the magnetic
layer.

[0003]

Conventionally, an aluminum alloy substrate has been used as a substrate for a
magnetic recording medium to be used in magnetic recording devices, but a glass
20 substrate which is hard compared with the aluminum alloy substrate and is excellent in
flatness and smoothness is becoming mainstream along with the demand of an increase
in recording density.

[0004]

In recent years, a magnetic recording medium using an energy-assisted
25 magnetic recording method, that is, an energy-assisted magnetic recording medium has
been investigated in order to respond to increasing needs of an increase in recording

density. Also in an energy-assisted magnetic recording medium, a glass substrate for a magnetic recording medium can be used as a substrate, and a magnetic layer etc. can be disposed on a main surface of the glass substrate for a magnetic recording medium.

[0005]

5 In an energy-assisted magnetic recording medium, an ordered alloy having a high magnetic anisotropy coefficient K_u (hereinafter, also referred to as “high K_u ”) is used as a magnetic material of a magnetic layer. In order to realize the high K_u by increasing a degree of order (ordering degree), heat treatment may be performed with respect to a base material including a glass substrate for a magnetic recording medium
10 at a high temperature of 600°C or higher, at the time of, before, or after forming a magnetic layer.

[0006]

The heat treatment at a high temperature is performed at the time of, before, or after forming a magnetic layer, because coercivity can be increased as an annealing
15 temperature increases, regarding an Fe-Pt-based alloy or the like which is suitable for a magnetic material of a magnetic layer of an energy-assisted magnetic recording medium, for example.

[0007]

As described above, heat treatment may also be performed with respect to a
20 glass substrate for a magnetic recording medium at a high temperature during manufacturing of a magnetic recording medium, and therefore, a glass substrate for a magnetic recording medium is also required to have heat resistance.

[0008]

Patent Document 1, for example, discloses a glass substrate for an information
25 recording medium with which a magnetic recording layer can be formed at a high temperature. Specifically, Patent Document 1 discloses a glass substrate for an

information recording medium (provided that, a crystallized glass substrate and a strengthened glass substrate are excluded) including, in terms of mol%, 62% to 74% of SiO₂, 7% to 18% of Al₂O₃, 2% to 15% of B₂O₃, and 8% to 16% of the total content of any one or more components of MgO, CaO, SrO and BaO, in which the total content of the above-described seven components is 95% or more, and any one or more components of Li₂O, Na₂O and K₂O is contained in the total content of less than 1% or none of these three components is contained.

BACKGROUND ART DOCUMENT

10 PATENT DOCUMENT

[0009]

Patent Document 1: Japanese Patent No. 5056983

SUMMARY OF THE INVENTION

15 PROBLEMS THAT THE INVENTION IS TO SOLVE

[0010]

However, in a case of performing heat treatment at a high temperature as described above, a rapid temperature change before and after the heat treatment occurs in a glass substrate for a magnetic recording medium, and thus, rapid thermal expansion or thermal contraction occurs in the glass substrate for a magnetic recording medium and great stress is applied to the glass substrate for a magnetic recording medium. In addition, heat cracking may occur in the glass substrate for a magnetic recording medium due to the stress applied, and the substrate may be broken according to a degree of heat cracking. As described above, when heat cracking occurs in a glass substrate for a magnetic recording medium or the substrate is broken during manufacturing of a magnetic recording medium, not only a yield ratio decreases, but also it is necessary to

collect the broken substrate and clean a heat treatment device, whereby the productivity significantly decreases.

[0011]

Therefore, an aspect of the present invention is made in consideration of the
5 problems in the related art as described above, and an object thereof is to provide a glass substrate for a magnetic recording medium in which heat cracking is prevented from occurring in a case where a rapid temperature change is applied.

MEANS FOR SOLVING THE PROBLEMS

10 [0012]

In an aspect of the present invention for solving the above-mentioned problems, there is provided a glass substrate for a magnetic recording medium, having a doughnut shape and including: a pair of main surfaces; an outer peripheral edge; and an inner peripheral edge, in which the outer peripheral edge includes an outer peripheral side
15 surface part and a pair of outer peripheral chamfered parts, an arithmetic average roughness R_a of the outer peripheral side surface part is $0.1\ \mu\text{m}$ or smaller, and an arithmetic average roughness R_a of an etched outer peripheral side surface part obtained after etching $5\ \mu\text{m}$ of the outer peripheral side surface part from a surface thereof is $0.5\ \mu\text{m}$ or smaller, and a maximum height roughness R_z of the etched outer peripheral side
20 surface part is $10\ \mu\text{m}$ or smaller.

ADVANTAGE OF THE INVENTION

[0013]

According to an aspect of the glass substrate for a magnetic recording medium
25 of the present invention, it is possible to provide a glass substrate for a magnetic

recording medium in which heat cracking is prevented from occurring in a case where a rapid temperature change is applied.

BRIEF DESCRIPTION OF THE DRAWINGS

5 [0014]

Fig. 1 is an explanatory diagram of a glass substrate for a magnetic recording medium according to an embodiment of the present invention.

Fig. 2 is an explanatory diagram of a micro crack generating in the glass substrate for a magnetic recording medium.

10 Figs. 3(A) and 3(B) are laser microscopic images of a surface of an outer peripheral side surface part before and after etching in Experiment Example 1 of the present invention. Fig. 3(A) shows an image before the etching and Fig. 3(B) shows an image after the etching.

15 Figs. 4(A) and 4(B) are laser microscopic images of a surface of an outer peripheral side surface part before and after etching in Experiment Example 10 of the present invention. Fig. 4(A) shows an image before the etching and Fig. 4(B) shows an image after the etching.

MODE FOR CARRYING OUT THE INVENTION

20 [0015]

Hereinafter, an embodiment for carrying out the present invention will be described with reference to the drawings, but the present invention is not limited to the embodiment and various modifications and replacements of the following embodiment can be performed without departing from a scope of the present invention.

25 (Glass Substrate For Magnetic Recording Medium)

A configuration example of a glass substrate for a magnetic recording medium of the present embodiment will be described.

[0016]

5 A glass substrate for a magnetic recording medium of the present embodiment is a glass substrate for a magnetic recording medium, having a doughnut shape and including a pair of main surfaces, an outer peripheral edge, and an inner peripheral edge, and the outer peripheral edge includes an outer peripheral side surface part and a pair of outer peripheral chamfered parts.

[0017]

10 In addition, an arithmetic average roughness Ra of the outer peripheral side surface part is 0.1 μm or smaller, and an arithmetic average roughness Ra of an etched outer peripheral side surface part obtained after etching 5 μm of the outer peripheral side surface part from the surface thereof is 0.5 μm or smaller.

[0018]

15 First, a structure of the glass substrate for a magnetic recording medium of the present embodiment (hereinafter, also simply referred to as a “glass substrate”) will be described with reference to Fig. 1.

[0019]

20 Fig. 1 schematically shows a cross-sectional perspective view of the glass substrate of the present embodiment. Fig. 1 is a cross-sectional perspective view including a cross section of a plane which passes the center of a glass substrate 10 and is perpendicular to main surfaces 121 and 122. That is, Fig. 1 shows half of the glass substrate of the present embodiment together with a cross sectional view thereof.

[0020]

25 As recognized from Fig. 1, the glass substrate 10 has a circular outer periphery and has a circular plate shape in which a circular cored part (center cored part) 11 is

provided at the center part thereof to be concentric with the outer periphery, namely a doughnut shape.

[0021]

The upper and lower surfaces thereof are main surfaces 121 and 122. The
5 glass substrate 10 includes an outer peripheral edge 13 positioned in the outer periphery
and an inner peripheral edge 14 positioned in the inner periphery.

[0022]

The outer peripheral edge 13 and the inner peripheral edge 14 respectively
include chamfered parts on sides of the main surfaces 121 and 122. That is, the outer
10 peripheral edge 13 and the inner peripheral edge 14 respectively include a pair of
chamfered parts. Specifically, the outer peripheral edge 13 includes outer peripheral
chamfered parts 131 and 133, and the inner peripheral edge 14 includes inner peripheral
chamfered parts 141 and 143, respectively.

[0023]

15 The side surface part is formed between the chamfered parts. The outer
peripheral edge 13 includes an outer peripheral side surface part 132, and the inner
peripheral edge 14 includes an inner peripheral side surface part 142, respectively.
The outer peripheral side surface part 132 and the inner peripheral side surface part 142
may be formed to be approximately perpendicular to the main surfaces 121 and 122,
20 respectively.

[0024]

As described above, the outer peripheral edge 13 may include the outer
peripheral side surface part 132 and the outer peripheral chamfered parts 131 and 133,
and the inner peripheral edge 14 may include the inner peripheral side surface part 142
25 and the inner peripheral chamfered parts 141 and 143.

[0025]

A size of the glass substrate 10 of the present embodiment is not particularly limited and can be arbitrarily selected according to the specification of the glass substrate. A diameter D of the glass substrate of the present embodiment can be set as a size corresponding to the specification required to the glass substrate, for example, 48
5 mm, 65 mm, or 95 mm. Particularly, the diameter of the glass substrate of the present embodiment is preferably 65 mm or more which has been highly required in recent years.

[0026]

By the way, when performing heat treatment at a high temperature which is
10 600°C or higher, for example, from 600°C to 700°C, in a manufacturing step of an energy-assisted magnetic recording medium as described above, a rapid temperature change may be applied to the glass substrate and heat cracking may occur in the glass substrate according to stress applied.

[0027]

15 Therefore, the inventors of the present invention have investigated a glass substrate in which heat cracking can be prevented from occurring in a case where a rapid temperature change is applied.

[0028]

First, the inventors of the present invention have investigated causes of the
20 occurrence of heat cracking in a case where a rapid temperature change is applied.

[0029]

Stress is easily applied to portions where expansion and contraction easily occur when a rapid temperature change is applied the glass substrate. Accordingly, when the portions where expansion and contraction easily occur according to a rapid
25 temperature change were investigated, it was found that expansion and contraction

easily occur in outer peripheral parts of the glass substrate due to an influence of a shape.

[0030]

5 In general, heat treatment is performed in a state where a plurality of portions of the outer peripheral side surface part of the glass substrate are held by using a metal holder, and it is found that temperature distribution in the glass substrate particularly rapidly changes depending on heat transfer between the holder and the glass substrate.

[0031]

10 Accordingly, when performing the heat treatment, there is a high possibility that the outer peripheral parts of the glass substrate are particularly exposed to a rapid temperature change. It is found that, in a case of being exposed to a rapid temperature change, expansion and contraction easily occur in the outer peripheral parts, and thus, stress is easily applied thereto.

[0032]

15 Therefore, next, when the inventors of the present invention have investigated a relationship of the properties of the outer peripheral side surface part and the occurrence of heat cracking, it is found that, in a case where a micro crack having a depth of several μm to submicron is present in the outer peripheral side surface part, stress is concentrated to a crack tip and this easily causes the occurrence of large cracking due to
20 extension of the crack.

[0033]

Herein, Fig. 2 schematically shows a micro crack. Fig. 2 schematically shows a cross section of a micro crack on a plane which is parallel to a depth direction of a micro crack 22 and passes the micro crack.

25 [0034]

For example, as shown in Fig. 2, the micro crack 22 generated in the outer peripheral side surface part of the glass substrate is generated towards the inner portion from a surface 21 of the outer peripheral side surface part of the glass substrate. In a case where a micro crack is generated, the stress concentration to the tip of the micro crack 22 is correlated to a width R of the crack tip, and when the width R is small, stress is particularly easily concentrated to the micro crack 22. Accordingly, it is possible to obtain a glass substrate in which heat cracking is prevented from occurring in a case where a rapid temperature change is applied, by decreasing the number of micro cracks in the outer peripheral side surface part.

[0035]

However, regarding the micro crack 22 having a significantly small width R of the tip which particularly easily becomes a cause of the occurrence of heat cracking, a width of an opening part 221 on the surface 21 side is small or the opening part 221 is covered with a hydrate or the like in many cases. Therefore, such a micro crack is hardly detected from the surface 21 of the outer peripheral side surface part of the glass substrate. Accordingly, it has been difficult to measure an existence frequency and a depth of a micro crack in the outer peripheral side surface part of the glass substrate by using a surface roughness tester etc.

[0036]

Therefore, when a detecting method of such a micro crack is investigated, it is found that, by etching (etching treatment) the outer peripheral side surface part of the glass substrate, a micro crack which is not detected before etching may be revealed in the outer peripheral side surface part. This may be because a hydrate or the like covering a micro crack can be removed by etching, and a size of an opening part (pit) on the surface side of the micro crack can be increased by etching.

[0037]

From the above-mentioned investigated result, it is found that, since a micro crack of the outer peripheral side surface part can be revealed by etching the outer peripheral side surface part thereby being able to detect by a surface roughness tester etc., an existence frequency and a depth of a micro crack of the outer peripheral side surface part can be quantitatively recognized. In addition, it is found that the arithmetic average roughness Ra of the outer peripheral side surface part of the substrate after etching is correlated with a generation ratio of heat cracking.

[0038]

Therefore, in the glass substrate of the present embodiment, the arithmetic average roughness Ra of the outer peripheral side surface part after etching 5 μm of the outer peripheral side surface part from the surface thereof, that is, the etched outer peripheral side surface part, is 0.5 μm or smaller, preferably 0.3 μm or smaller, and more preferably 0.2 μm or smaller.

[0039]

As described above, a micro crack is revealed by etching in the etched outer peripheral side surface part, and the existence frequency of a micro crack contained in the outer peripheral side surface part can be evaluated by evaluating the arithmetic average roughness Ra of the etched outer peripheral side surface part. That is, as the arithmetic average roughness Ra of the etched outer peripheral side surface part becomes smaller, the existence frequency of a micro crack contained in the outer peripheral side surface part decreases.

[0040]

According to the investigation of the inventors of the present invention, it is possible to sufficiently decrease the existence frequency of a micro crack and to prevent the occurrence of heat cracking, in a case where the arithmetic average roughness Ra of the etched outer peripheral side surface part is 0.5 μm or smaller. Therefore, the above

configuration is preferable because it is possible to prevent the occurrence of heat cracking in the glass substrate in a case where rapid temperature change is applied.

[0041]

In the glass substrate of the present embodiment, an etching amount when
5 measuring the arithmetic average roughness Ra of the etched outer peripheral side surface part is set to 5 μm , but the same tendency may be obtained, as long as the etching amount is from 1 μm to 20 μm . Accordingly, the etching amount is not limited to 5 μm and can be selected from a range of 1 μm to 20 μm .

[0042]

10 In a case where the etching amount is smaller than 1 μm , a size of an opening part of a micro crack on the surface of the etched outer peripheral side surface part may not become sufficiently large, and an existence frequency of a micro crack or a specific shape thereof may hardly be evaluated. Meanwhile, in a case where the etching amount is larger than 20 μm , a size of an opening part of a micro crack on the surface of
15 the etched outer peripheral side surface part may become excessively large, an existence frequency and a size of an original crack may not be reflected, and accordingly, appropriate evaluation may not be performed.

[0043]

Accordingly, in a case of performing evaluation of the arithmetic average
20 roughness Ra or a maximum height roughness Rz, which will be described later, of the etched outer peripheral side surface part, the etching amount is preferably from 1 μm to 20 μm and particularly preferably 5 μm .

[0044]

In the glass substrate of the present embodiment, the arithmetic average
25 roughness Ra of the outer peripheral side surface part before performing etching is 0.1 μm or smaller and preferably 0.05 μm or smaller.

[0045]

This may be because a polishing abrasive or the like is easily attached, and dust is generated at the time of cleaning or film forming, thereby causing contamination on a main surface, in a case where the arithmetic average roughness Ra of the outer peripheral side surface part is larger than 0.1 μm , as will be described later.

[0046]

In addition, the maximum height roughness Rz of the etched outer peripheral side surface part is 10 μm or smaller, preferably 4 μm or smaller, and more preferably 3 μm or smaller.

[0047]

The maximum height roughness Rz may correspond to a maximum depth of a micro crack present in a measurement region. As a depth of a micro crack becomes larger, the heat cracking is easily caused. Accordingly, in a case where the maximum height roughness Rz is 10 μm or smaller, a maximum depth of a micro crack is sufficiently shallow and it is possible to prevent the occurrence of heat cracking in the glass substrate in a case where a rapid temperature change is applied.

[0048]

A method of etching the outer peripheral side surface part of the glass substrate is not particularly limited, and etching can be performed by dipping a glass substrate in an etching solution for a predetermined period of time. In a case of dipping a glass substrate in an etching solution, the entire surface of the glass substrate is uniformly etched, and accordingly, in a case of etching 5 μm of the outer peripheral side surface part from a surface thereof, for example, the diameter of the glass substrate is decreased by 10 μm .

[0049]

The etching solution is not particularly limited as long as it is a material capable of etching a glass substrate, and a mixed aqueous solution of hydrofluoric acid and hydrochloric acid can be used, for example. Since the etching time changes depending on an etching solution or a glass material of a glass substrate, it is preferable to perform
5 a preliminary test in advance, for example, to check the time necessary for performing etching of 5 μm with respect to the surface of the glass substrate.

[0050]

The arithmetic average roughness Ra or the maximum height roughness Rz is defined in JIS B 0601 (2013) and can be evaluated by using a laser microscope, a
10 contact-type surface roughness tester, or a white-light interference microscope.

[0051]

Regarding the glass substrate of the present embodiment, a glass substrate before etching 5 μm of the outer peripheral side surface part from a surface thereof can be used as a glass substrate for a magnetic recording medium.

15 [0052]

As clearly shown from the fact that a micro crack is revealed in the glass substrate in which the etching has been performed to the surface of the outer peripheral side surface part thereof, although heat cracking is prevented due to the increased width R of the tip of the micro crack, the arithmetic average roughness Ra of the outer
20 peripheral side surface part after etching increases more than that before etching. Accordingly, a polishing abrasive or the like is easily attached to the outer peripheral side surface part, and problems in which the polishing abrasive which has been attached during various polishing steps is carried into cleaning step may occur.

[0053]

25 A micro crack is generated mainly depending on manufacturing conditions of a glass substrate. Accordingly, regarding the outer peripheral side surface part of a glass

substrate which is manufactured under the same conditions as those at the time of practical manufacturing, in advance, the arithmetic average roughness Ra before and after etching or the maximum height roughness Rz, in some cases, is evaluated and the manufacturing conditions can be selected so as to satisfy the definition of the glass substrate of the present embodiment.

[0054]

Alternatively, when manufacturing a glass substrate, a plurality of glass substrates per lot are generally manufactured. Since the glass substrates are manufactured in the same lot under the same conditions, an existence frequency and a maximum depth of a micro crack generated in an outer peripheral side surface part thereof is also at the same level. Accordingly, one or more glass substrates for evaluation are selected from the same lot, and the arithmetic average roughness Ra before and after etching or the maximum height roughness Rz, in some cases, is evaluated with respect to the glass substrates for evaluation. Then, it is possible to confirm that the glass substrates in the lot satisfy the definition of the glass substrate of the present embodiment.

[0055]

As described above, in a case where a rapid temperature change is applied to the glass substrate, a micro crack contained mainly in the outer peripheral side surface part becomes a starting point of heat cracking. Accordingly, in a case where the arithmetic average roughness Ra before etching the outer peripheral side surface part and the arithmetic average roughness Ra after etching 5 μm of the outer peripheral side surface part from a surface thereof satisfy the definition described above, it is possible to prevent the occurrence of heat cracking, even in a case where a rapid temperature change is applied.

[0056]

However, the properties of the outer peripheral chamfered parts or the inner peripheral edge may also affect the occurrence of the heat cracking, due to a shape of a substrate holder for a glass substrate, a holding position or a change in temperature distribution at the time of temperature rising and temperature falling when performing heat treatment at a high temperature.

[0057]

Thus, in addition to the outer peripheral side surface part, it is also preferable that the arithmetic average roughness Ra before etching of the outer peripheral chamfered parts 131 and 133, the inner peripheral chamfered parts 141 and 143, and the inner peripheral side surface part 142 described above with reference to Fig. 1, and the arithmetic average roughness Ra after etching 5 μm from a surface of each part described above, and in some cases, the maximum height roughness Rz after the etching of each part described above satisfy the same definitions as that of the outer peripheral side surface part described above.

[0058]

It is also preferable that the arithmetic average roughness Ra before etching of a corner between a main surface and a chamfered part and a corner between a side surface part and a chamfered part, and the arithmetic average roughness Ra after etching of 5 μm from a surface of each of the corners, and in some cases, the maximum height roughness Rz after etching of each of the corners satisfy the same definitions as that of the outer peripheral side surface part described above.

[0059]

The corner between a main surface and a chamfered part means each corner between the main surfaces 121 and 122, and the outer peripheral chamfered parts 131 and 133 and the inner peripheral chamfered parts 141 and 143 in Fig. 1. In addition, the corner of a side surface part and a chamfered part means each corner between the

outer peripheral chamfered parts 131 and 133 and the outer peripheral side surface part 132, and each corner between the inner peripheral chamfered parts 141 and 143 and the inner peripheral side surface part 142.

[0060]

5 The glass substrate of the present embodiment may be subjected to chemical strengthening, in advance. This is because the occurrence of heat cracking can be particularly prevented in a case where a rapid temperature change is applied, by performing chemical strengthening in advance.

[0061]

10 In a case of subjecting a glass substrate to chemical strengthening, in order to prevent particularly the influence of a micro crack contained in the outer peripheral side surface part,, it is preferable to perform the chemical strengthening, in advance, at least with respect to a portion containing the outer peripheral side surface part. In a case of performing the chemical strengthening, it is preferable to perform the chemical
15 strengthening, in advance, particularly with respect to the entire surface of the glass substrate.

[0062]

 In a case of performing the chemical strengthening, a degree thereof is not particularly limited, but it is preferable that, at least in the outer peripheral side surface
20 part of the glass substrate, a compressive stress depth DOL obtained by performing a chemical strengthening treatment satisfies $1\ \mu\text{m} \leq \text{DOL} \leq 15\ \mu\text{m}$. It is particularly preferable that, in the entire surface of the glass substrate, the compressive stress depth DOL obtained by performing a chemical strengthening treatment satisfies $1\ \mu\text{m} \leq \text{DOL} \leq 15\ \mu\text{m}$.

25 [0063]

This is because the chemical strengthening is sufficiently performed and heat cracking can be particularly prevented, in a case where the compressive stress depth DOL is 1 μm or more. However, when the DOL exceeds 15 μm , flatness of the glass substrate may be deteriorated due to diffusion of ions to inside of the glass substrate, in
5 a case of performing heat treatment at a high temperature of 600°C or higher, and accordingly, the DOL is preferably 15 μm or smaller. Also from this point, a glass substrate used in a process where heat treatment at a high temperature of 600°C or higher is required, receives a significant influence of a micro crack, and removal thereof is important.

10 [0064]

A glass material configuring the glass substrate of the present embodiment is not particularly limited and various glass materials can be used.

[0065]

As described above, in the glass substrate of the present embodiment, heat
15 cracking can be prevented by setting the arithmetic average roughness Ra of the outer peripheral side surface part and the arithmetic average roughness Ra of the etched outer peripheral side surface part after etching 5 μm of the outer peripheral side surface part from a surface thereof to be in a predetermined range.

[0066]

20 However, for glass materials used in the glass substrate, it is preferable to use a glass substrate in which heat cracking hardly occurs, even in a case where a rapid temperature change is applied.

[0067]

Accordingly, the glass substrate of the present embodiment is preferably
25 formed of a glass material having a thermal expansion coefficient in a temperature range of 50°C to 350°C of $70 \times 10^{-7}/^\circ\text{C}$ or smaller, and is more preferably formed of a

glass material having a thermal expansion coefficient in a temperature range of 50°C to 350°C of $55 \times 10^{-7}/^{\circ}\text{C}$ or smaller.

[0068]

This is because, in a case where the thermal expansion coefficient in a temperature range of 50°C to 350°C is $70 \times 10^{-7}/^{\circ}\text{C}$ or smaller, expansion and contraction of a glass substrate accompanied with a temperature change can be prevented, and accordingly, even in a case where a rapid temperature change is applied, heat cracking can be prevented from occurring in accordance with the properties of the outer peripheral side surface part.

[0069]

A lower limit value of the thermal expansion coefficient in a temperature range of 50°C to 350°C is not particularly limited, and for example, a glass material having the thermal expansion coefficient in a temperature range of 50°C to 350°C of greater than 0 can be used for the glass substrate of the present embodiment.

[0070]

As described above, in the glass substrate of the present embodiment, the occurrence of heat cracking can be prevented, even in a case where a rapid temperature change is applied. Accordingly, the glass substrate can be particularly suitably used as a glass substrate for an energy-assisted magnetic recording medium in which a rapid temperature change may be applied in a manufacturing step thereof. When manufacturing an energy-assisted magnetic recording medium, it is general to perform heat treatment at a high temperature of approximately from 600°C to 700°C at the time of forming a magnetic layer, in order to promote the ordering of an Fe-Pt-based magnetic layer alloy (magnetic material) contained in a magnetic layer. Accordingly, in order to prevent the occurrence of a strain or a deformation in a glass substrate when performing such heat treatment at a high temperature, the glass substrate of the present

embodiment is preferably formed of a glass material having a glass transition point T_g of 650°C or higher, and is more preferably formed of a glass material having a glass transition point T_g of 700°C or higher.

[0071]

5 As described above, a rapid temperature change may be applied to a glass substrate, when performing heat treatment at a high temperature of 600°C or higher particularly when manufacturing an energy-assisted magnetic recording medium, and heat cracking may occur in a glass substrate of the related art. Meanwhile, according to the glass substrate of the present embodiment, the arithmetic average roughness R_a of
10 the outer peripheral side surface part and the arithmetic average roughness R_a of the etched outer peripheral side surface part after etching $5\text{ }\mu\text{m}$ of the outer peripheral side surface part from the surface thereof are set to be in a predetermined range. Accordingly, since an existence frequency of a micro crack which is contained in the outer peripheral side surface part and is to be a starting point of heat cracking is
15 sufficiently low, it is possible to prevent the occurrence of heat cracking in a case where a rapid temperature change is applied.

[0072]

Thus, the glass substrate of the present embodiment can be particularly suitably used as a glass substrate for a magnetic recording medium, for an energy-assisted
20 magnetic recording medium.

[0073]

The use application of the glass substrate of the present embodiment is not limited to a glass substrate for an energy-assisted magnetic recording medium and the glass substrate can be suitably used as a glass substrate for various magnetic recording
25 media.

[0074]

Next, a configuration example of a manufacturing method for a magnetic recording medium of the present embodiment described above (hereinafter, also simply referred to as a “manufacturing method of a glass substrate”) will be simply described.

[0075]

5 According to the manufacturing method of a glass substrate of the present embodiment, it is possible to manufacture the glass substrate for a magnetic recording medium described above. Accordingly, the description of the parts overlapping with the content described with respect to the glass substrate for a magnetic recording medium will be partially omitted.

10 [0076]

The manufacturing method of the glass substrate of the present embodiment may include the following Step 1 to Step 5, for example.

(Step 1) a shape-processing step of processing a glass sheet into a glass substrate having a circular plate shape having a circular hole at the center thereof.

15 (Step 2) a chamfering step of performing chamfering of edge parts of an inner periphery and an outer periphery of the glass substrate.

(Step 3) an edge polishing step of polishing edges (inner peripheral edge and outer peripheral edge) of the glass substrate.

20 (Step 4) a main surface polishing step of polishing main surfaces of the glass substrate.

(Step 5) a cleaning and drying step of cleaning and drying the glass substrate.

[0077]

Herein, the shape-processing step of (Step 1) is a step of processing a glass sheet formed by a float process, a fusion process, a press molding process, a downdraw process or a redraw process is processed into a glass substrate having a circular plate shape having a circular hole at the center thereof. The glass sheet used may be

25

amorphous glass, crystallized glass, or strengthened glass including a strengthening layer on a surface layer thereof.

[0078]

5 In the chamfering step of (Step 2), the inner peripheral edges and outer peripheral edges can be chamfered. By performing the chamfering step, the inner peripheral chamfered parts 141 and 143 can be formed on the inner peripheral edge 14 and the outer peripheral chamfered parts 131 and 133 can be formed on the outer peripheral edge 13, as described above with reference to Fig. 1.

[0079]

10 In the edge polishing step of (Step 3), the edges (side surface part and the chamfered parts) of the glass substrate can be edge-polished.

[0080]

15 In the main surface polishing step of (Step 4), a polishing slurry is supplied to main surfaces of a glass substrate having a doughnut shape and the upper and lower main surfaces of a glass substrate having a doughnut shape can be polished at the same time by using a double side polishing machine. In the main surface polishing step, only the primary polishing may be conducted, the primary polishing and the secondary polishing may be performed, or the tertiary polishing may be performed after the secondary polishing.

20 [0081]

In the main surface polishing step of (Step 4), lapping (for example, loose abrasive lapping or fixed abrasive lapping) of main surfaces may be performed before performing the primary polishing of the main surfaces. In this case, only the primary lapping may be performed or a plurality of lapping steps such as secondary lapping and
25 the like can be performed.

[0082]

In addition, between the steps, cleaning of the glass substrate (in-process cleaning) and etching of the glass substrate surface (in-process etching) may be performed. Herein, the lapping of the main surfaces is main surface polishing in the broad sense.

5 [0083]

The cleaning and drying step of (Step 5) is a step of cleaning and drying the glass substrate after polishing. A specific cleaning method is not particularly limited. For example, the cleaning can be performed by scrub cleaning using a detergent, ultrasonic cleaning in a state of being dipped in a detergent solution, or ultrasonic
10 cleaning in a state of being dipped in pure water, and the like. Also, the drying method is not particularly limited, and for example, the drying can be performed with isopropyl alcohol vapor.

[0084]

In addition, between the steps, cleaning of the glass substrate (in-process
15 cleaning) and etching of the glass substrate surface (in-process etching) may be performed. Moreover, in the case where the glass substrate is required to have high mechanical strength, a strengthening step (for example, a chemical strengthening step) of forming a strengthening layer on a surface layer of the glass substrate may be conducted before or after the polishing steps or between the polishing steps exemplified
20 as Steps 3 and 4.

[0085]

Steps 1 to 5 described above are not necessarily performed in the order described above, and the main surface polishing step may be performed before the shape-processing step, for example. Each step is not limited to be performed once and
25 the steps may be performed an arbitrary number of times according to the required specification of the glass substrate. For example, it is possible to perform the main

surface polishing step after the shape-processing step, and then perform the chamfering step and the edge polishing step, followed by performing the main surface polishing step again.

[0086]

5 However, regarding the glass substrate of the present embodiment, an existence frequency of a micro crack in the outer peripheral side surface part is preferably low, as described above. The following two cases may mainly be mentioned as causes of generation of a micro crack contained in the outer peripheral side surface part.

10 (Cause 1) In the chamfering step of Step 2, not only the outer peripheral chamfered parts, but also the outer peripheral side surface part is lapped, but a micro crack is generated in the outer peripheral side surface part at that time and cannot be sufficiently removed in the edge polishing step of Step 3.

15 (Cause 2) In the main surface polishing step of Step 4, the glass substrate to be subjected to the main surface polishing step is inserted into and held by a circular hole formed in a carrier, and the main surface of the glass substrate can be polished by using a double side polishing machine, and the glass substrate held by the hole of the carrier is also rotated at the time of polishing. Scratches may be made due to rubbing between the carrier and the glass substrate at that time.

[0087]

20 Therefore, in order to cope with Cause 1, it is preferable to perform the preliminary test, and adjust the removal amount in the edge polishing step, so as to ensure the removal of a micro crack.

[0088]

25 In addition, in order to cope with Cause 2, there may be mentioned a method of adopting a carrier using a material which hardly causes a micro crack in a glass

substrate, as the carrier used in the main surface polishing step, or a method of performing the edge polishing step of Step 3 after the main surface polishing step.

[0089]

In general, stainless steel, steel, or a glass fiber-containing epoxy resin is used as a material of a carrier holding a glass substrate in the main surface polishing step, and these materials have high hardness or contain a substance having high hardness. Accordingly, a micro crack may be generated in the outer peripheral side surface part, by rubbing of the carrier and the outer peripheral side surface part of glass during the main surface polishing.

[0090]

On the other hand, it is possible to prevent generation of a micro crack, in a case where one or more kinds selected from an aramid fiber-containing epoxy resin, carbon, a polyvinyl chloride resin, polycarbonate, bakelite, an epoxy resin and a polyester resin, is/are used as a material of at least a portion coming into contact with the glass substrate, of a carrier used in the main surface polishing step. Accordingly, it is possible to prevent generation of a micro crack due to Cause 2 by using such a carrier. In a case of performing the main surface polishing step several times, it is possible to prevent generation of a micro crack due to Cause 2 by using a carrier using the predetermined material in at least the portion coming into contact with the glass substrate, at least in the finally-performed main surface polishing step.

[0091]

As a material of at least the portion coming into contact with the glass substrate, of the carrier used in the main surface polishing step, it is more desirable to use a material of one or more kinds selected from a polyvinyl chloride resin, polycarbonate, bakelite, an epoxy resin, and a polyester resin which are softer resins.

[0092]

The entire carrier can be configured with one or more kinds selected from a group of the materials described above. In order to prevent the generation of a micro crack in the outer peripheral side surface part of the glass substrate while maintaining the strength of the carrier, it is possible to use a carrier in which one or more materials
5 selected from a group of the materials described above is used in a portion of the hole thereof for holding the glass substrate, which comes into contact with the glass substrate, while a material having high strength such as stainless steel is used for a main body thereof.

[0093]

10 A manufacturing method of a carrier obtained by combining a main body formed of a material having high strength such as stainless steel and a hole portion which holds a glass substrate and is formed of a material selected from a group of the materials described above is not particularly limited. For example, there may be mentioned a method of coating a surface of a hole provided in a carrier for holding a
15 glass substrate with a resin, or a method of preparing a hole portion for holding a glass substrate with resin and joining the hole portion with the carrier main body.

[0094]

In order to cope with Cause 2, in a case of performing the edge polishing step of Step 3 after the main surface polishing step, it is preferable to measure a maximum
20 depth of a micro crack generated in the main surface polishing step, in advance, and select conditions of the edge polishing step so as to remove the micro crack.

[0095]

It is possible to manufacture the glass substrate described above by using the manufacturing method of the glass substrate including each step described above.

25 [0096]

In addition, the glass substrate obtained by using the manufacturing method including each step described above can be formed into a magnetic recording medium, by further performing a step of forming a thin film such as a magnetic layer on the main surface thereof.

5 [Magnetic recording medium]

Next, a configuration example of a magnetic recording medium of the present embodiment will be described.

[0097]

The magnetic recording medium of the present embodiment may contain the
10 glass substrate for a magnetic recording medium described above.

[0098]

A recording method or the like of the magnetic recording medium of the present embodiment is not particularly limited, as long as the magnetic recording medium includes the glass substrate for a magnetic recording medium described above,
15 and various magnetic recording media such as the energy-assisted magnetic recording medium can be used. Herein, the energy-assisted magnetic recording medium will be described as an example.

[0099]

The configuration of the magnetic recording medium of the present
20 embodiment is not limited, and for example, an adhesion layer, a base layer, a seed layer, a magnetic recording layer, a protective layer, and the like may be provided on the surface of the glass substrate for a magnetic recording medium, and these layers may be laminated on the glass substrate, for example, in this order. In addition, arbitrary layers can be provided instead of or in addition to the layers described above.

25 [0100]

A configuration example of each layer will be described below.

[0101]

An adhesion layer can be provided for increasing adhesion between a layer formed on the adhesion layer and a layer formed below the adhesion layer. As a material for forming the adhesion layer, one or more kinds of metal selected from Ni, W, Ta, Cr, and Ru can be contained, for example, and an alloy containing metal selected from a group of the metals described above can also be contained.

[0102]

The adhesion layer can be configured with single layer, but can also have a laminated structure with two or more layers.

[0103]

In addition, a soft magnetic backing layer can also be arbitrarily provided between the glass substrate and a magnetic recording layer, for example.

[0104]

The soft magnetic backing layer can improve recording and reproduction characteristics of a magnetic recording medium by controlling a magnetic flux from a magnetic head. A material for forming the soft magnetic backing layer is not particularly limited, and for example, a crystalline material such as a NiFe alloy, a sendust (FeSiAl) alloy and a CoFe alloy, a microcrystalline material such as FeTaC, CoFeNi and CoNiP, and an amorphous material containing a Co alloy such as CoZrNb and CoTaZr can be preferably used.

[0105]

A thickness of the soft magnetic backing layer is not particularly limited and can be selected in accordance with a structure and properties of a magnetic head used in magnetic recording, for example. In a case of forming the soft magnetic backing layer by using continuous film forming with other layers, the thickness of the soft magnetic backing layer is preferably from 10 nm to 500 nm.

[0106]

In addition, a heat sink layer can be arbitrarily provided. The heat sink layer can effectively absorb excessive heat of a magnetic recording layer, which generates at the time of energy-assisted magnetic recording. The heat sink layer is preferably
5 formed using a material having high thermal conductivity and specific heat capacity. Specifically, a Cu simple substance, an Ag simple substance, an Au simple substance, or an alloy material containing one or more kinds of metal selected from a group of the metal described above as a main component, can be used.

[0107]

10 Herein, the term “containing as a main component” means that a content ratio of the metal described above in the material is 50 wt% or more.

[0108]

The heat sink layer can be formed by using an Al-Si alloy or a Cu-B alloy in view of strength or the like.

15 [0109]

In addition, the heat sink layer can be formed by using a sendust (FeSiAl) alloy or a soft magnetic CoFe alloy, thereby imparting thereto a function of the soft magnetic backing layer, namely, a function of concentrating a perpendicular magnetic field generated by a head to the magnetic recording layer.

20 [0110]

The thickness of the heat sink layer is not particularly limited, and can be selected according to a calorific value and heat distribution at the time of energy-assisted magnetic recording, a layer configuration of the magnetic recording medium, the thickness of each configuration layer, and the like, for example. The thickness of
25 the heat sink layer is, for example, preferably from 10 nm to 100 nm.

[0111]

A forming method of the heat sink layer is not particularly limited, and the heat sink layer can be formed by using a sputtering method, for example. The heat sink layer can be provided between the glass substrate and the magnetic recording layer, for example, and can be provided between the glass substrate and the adhesion layer or
5 between the adhesion layer and the base layer, taking the properties required for the magnetic recording medium into consideration.

[0112]

Next, the base layer will be described.

[0113]

10 The base layer is a layer for blocking an influence of a crystalline structure of a layer formed below the base layer on crystal orientation of the magnetic recording layer and a size of magnetic crystal grains.

[0114]

In a case of providing the soft magnetic backing layer as described above, the
15 base layer is required to be nonmagnetic, in order to prevent magnetic influence on the soft magnetic backing layer.

[0115]

Examples of the material for forming the base layer include an oxide such as MgO and SrTiO₃, a nitride such as TiN, metal such as Cr and Ta, a NiW alloy, and a
20 Cr-based alloy such as CrTi, CrZr, CrTa and CrW.

[0116]

The forming method of the base layer is not particularly limited and a forming method such as a sputtering method can be used, for example.

[0117]

25 Next, a seed layer will be described.

[0118]

The seed layer is a layer for controlling a grain size and crystal orientation of magnetic crystal grains of a magnetic layer in a magnetic recording layer which comes into contact with the seed layer, while ensuring adhesion between the base layer and the magnetic recording layer. Specifically, the seed layer can promote separation between magnetic crystal grains containing $L1_0$ type ordered alloy and a nonmagnetic crystal grain boundary containing Ti in the magnetic layer formed on the seed layer, thereby increasing coercivity H_c of the magnetic recording layer containing the magnetic layer.

[0119]

The seed layer may contain Pt, for example, and is particularly preferably formed of Pt.

[0120]

The forming method of the seed layer is not particularly limited and a forming method such as a sputtering method and a vacuum deposition method can be used. The sputtering method includes a RF magnetron sputtering method, for example.

[0121]

The conditions at the time of forming the seed layer are not particularly limited, and it is preferable to perform the film forming in a state where a base material for forming a seed layer and containing a glass substrate is heated at a temperature of 250°C to 700°C, for example.

[0122]

The thickness of the seed layer is not particularly limited and is preferably 0.1 nm or more, more preferably from 0.5 nm to 50 nm, and further preferably from 1 nm to 20 nm, for example.

[0123]

The magnetic recording layer can contain one magnetic layer or a plurality of magnetic layers. Hereinafter, a magnetic layer coming into contact with the seed layer is referred to as a first magnetic layer.

[0124]

5 The magnetic layer may contain Fe, Pt, and Ti, for example. Specifically, the first magnetic layer may have a granular structure formed of magnetic crystal grains containing $L1_0$ type ordered alloy containing Fe and Pt, and a nonmagnetic crystal grain boundary containing Ti, for example.

[0125]

10 The $L1_0$ type ordered alloy configuring the magnetic crystal grains may further contain at least one kind of element selected from the group consisting of Ni, Mn, Ag, Au and Cr, for the purpose of a change of properties of the magnetic crystal grains. The desired change of properties contains a decrease in temperature required for ordering of the $L1_0$ type ordered alloy.

15 [0126]

In the magnetic crystal grains, not all atoms may have the ordered structure, as long as an ordering degree S indicating a degree of the ordered structure is a predetermined value or more. The measurement regarding the magnetic recording medium is performed by XRD and the ordering degree S can be calculated by using a
20 ratio between the measured value and a theoretical value at the time of completely ordering. In a case of the $L1_0$ type ordered alloy, the ordering degree S is calculated by using integrated intensity of (001) and (002) peaks derived from the ordered alloy. The ordering degree S can be obtained by dividing a value of a ratio of (002) peak integrated intensity to (001) peak integrated intensity measured as described above, by a
25 ratio of (002) peak integrated intensity to (001) peak integrated intensity theoretically calculated at the time of completely ordering. When the ordering degree S obtained as

described above is 0.5 or more, a practical magnetic anisotropy coefficient K_u is obtained for a magnetic recording medium.

[0127]

The nonmagnetic crystal grain boundary may contain Ti and is more preferably
5 configured with Ti. The first magnetic layer preferably contains 4 at% to 12 at% of Ti and more preferably contains 5 at% to 10 at% of Ti with respect to the total number of atoms in the first magnetic layer.

[0128]

The nonmagnetic crystal grain boundary contains Ti in the range described
10 above, whereby the separation between the magnetic crystal grains and the nonmagnetic crystal grain boundary can be promoted to rapidly increase the coercivity H_c of the magnetic layer.

[0129]

The magnetic recording layer may further include a second magnetic layer, in
15 addition to the first magnetic layer. It is possible to further improve performance of the magnetic recording medium by providing the second magnetic layer.

[0130]

A configuration of the second magnetic layer is not particularly limited, and the
second magnetic layer may have a Curie temperature T_c which is different from that of
20 the first magnetic layer and may be provided for the purpose of controlling T_c . By setting a recording temperature in view of both of the first magnetic layer and the second magnetic layer, it is possible to decrease a magnetic switching field as the entire magnetic recording medium, which is necessary at the time of recording.

[0131]

25 For example, as the second magnetic layer, a magnetic layer having a lower Curie temperature T_c than a Curie temperature T_c of the first magnetic layer is formed.

In addition, when a recording temperature is set to a middle temperature of the Curie temperatures of both magnetic layers, the magnetization of the second magnetic layer is lost at the time of recording and it is possible to decrease a magnetic field necessary for switching the recording. By doing so, it is possible to exhibit excellent magnetic recording performance by decreasing a generated magnetic field at the time of recording, which is required for the magnetic recording head.

[0132]

It is preferable that the second magnetic layer has also a granular structure, and it is preferable that the magnetic crystal grains of the first magnetic layer and the second magnetic layer are disposed so as to be the same position in a horizontal direction, that is, direction parallel to the glass substrate surface. This is because it is possible to improve performance such as a signal-to-noise ratio (SNR) by using the deposition described above.

[0133]

A material configuring the second magnetic layer is not particularly limited, and it is preferable that the magnetic crystal grains thereof are materials containing at least any of Co and Fe, for example. Particularly, it is preferable that the magnetic crystal grains contain one or more kinds selected from Pt, Pd, Ni, Mn, Cr, Cu, Ag and Au.

[0134]

As a material for the magnetic crystal grains of the second magnetic layer, a CoCr-based alloy, a CoCrPt-based alloy, a FePt-based alloy, or a FePd-based alloy can be used, for example. The magnetic crystal grains may have the ordered structure such as $L1_0$ type, $L1_1$ type, and $L1_2$ type, or a hcp structure (hexagonal close-packed structure) or a fcc structure (face-centered cubic structure).

[0135]

As a material for the nonmagnetic crystal grains configuring the second magnetic layer, an oxide such as ZnO, SiO₂ and TiO₂, a nitride such as SiN and TiN, C, or B can be used, for example.

[0136]

5 As the second magnetic layer, a layer having a different composition may be used by using the same materials as those of the first magnetic layer. The second magnetic layer may be, for example, a layer obtained by changing a ratio of Ti in the first magnetic layer, a layer obtained by changing a ratio of an element such as Ni added to the ordered alloy, or the like.

10 [0137]

In addition, in the magnetic recording layer, an exchange bond control layer may be disposed between the first magnetic layer and the second magnetic layer, in order to adjust magnetic exchange bond between the first magnetic layer and the second magnetic layer.

15 [0138]

A protective layer can be provided on the upper surface of the magnetic recording layer, and the protective layer can be formed with materials which are commonly used in a field of a magnetic recording medium. Specifically, the protective layer can be formed by using a nonmagnetic metal such as Pt, a carbon-based
20 material such as diamond-like carbon, or a silicon-based material such as silicon nitride. The protective layer may be a single layer or may have a laminated structure. The protective layer having a laminated structure may have a laminated structure of two kinds of carbon-based materials having different properties from each other, a laminated structure of metal and a carbon-based material, or a laminated structure of a metal oxide
25 film and a carbon-based material.

[0139]

The protective layer can be formed by using an arbitrary method such as a sputtering method (including a DC magnetron sputtering method) and a vacuum deposition method.

[0140]

5 In addition, a liquid lubricant layer or the like can be further provided on the protective layer. The liquid lubricant layer can be formed using a perfluoropolyether-based lubricant, for example. The liquid lubricant layer can be formed by using a coating method such as a dip coating method and a spin coating method, for example.

[0141]

10 In the present embodiment, the energy-assisted magnetic recording medium has been described as a configuration example of the magnetic recording medium, but the present embodiment is not limited to the embodiment described above, even in a case of the energy-assisted magnetic recording medium. For example, various layers can be further provided, if necessary.

15 [0142]

The magnetic recording medium of the present embodiment described above includes the glass substrate for a magnetic recording medium described above. That is, the magnetic recording medium includes a glass substrate for a magnetic recording medium in which heat cracking is prevented from occurring in a case where a rapid
20 temperature change is applied. Accordingly, it is possible to manufacture the magnetic recording medium of the present embodiment with excellent productivity by preventing the occurrence of heat cracking in the glass substrate, when forming a magnetic layer.

EXAMPLES

25 [0143]

Hereinafter, the present invention will be described with reference to specific examples, but the present invention is not limited to these examples.

[0144]

First, an evaluation method of a glass substrate for a magnetic recording
5 medium of the following experiment examples will be described.

[0145]

(1) Arithmetic Average Roughness Ra of Outer Peripheral Side Surface Part
and Etched Outer Peripheral Side Surface Part, and Maximum Height Roughness Rz of
Etched Outer Peripheral Side Surface Part

10 The outer peripheral side surface part was observed by using a laser microscope
of Keyence Corporation (manufactured by Keyence Corporation, Violet Laser color 3D,
VK-9710, Laser Scanning Microscope), and the arithmetic average roughness Ra of the
outer peripheral side surface part and the etched outer peripheral side surface part, and
the maximum height roughness Rz of the etched outer peripheral side surface part were
15 calculated using the observation results.

[0146]

In the observation of the outer peripheral side surface part and the etched outer
peripheral side surface part, the measurement was performed by using a 50-powered
objective lens, setting a size of a measurement region to be $200\ \mu\text{m} \times 200\ \mu\text{m}$, and
20 disposing the center of the measurement region to become the center of the glass
substrate in a thickness direction.

[0147]

Analysis and calculation of the arithmetic average roughness Ra and the
maximum height roughness Rz were performed by using software VK analyzer (Ver.
25 1.1.0.0) for the above-mentioned laser microscope.

[0148]

At the time of analysis, since the outer peripheral side surface part and the etched outer peripheral side surface part of the glass substrate are curved surfaces, first, inclination correction of the curved surfaces was performed by using automatic secondary curved surface correction in X and Y directions. Thereafter, the arithmetic
5 average roughness Ra and the maximum height roughness Rz were calculated by setting a cutoff λ_s to 0.25 μm and λ_c to 80 μm .

[0149]

The etching of the outer peripheral side surface part was performed by using a mixed aqueous solution of a hydrofluoric acid and hydrochloric acid as an etching
10 solution and dipping the glass substrate to be evaluated in the etching solution.

[0150]

The concentration of hydrofluoric acid used in the etching solution was set to 1.0 wt% and the concentration of hydrochloric acid was set to 18 wt%.

[0151]

15 As described above, the entire glass substrate was dipped in the etching solution. Therefore, removal of 5 μm of the outer peripheral side surface part by performing the etching means that a disk outer diameter after the etching is decreased by 10 μm , compared to that before the etching.

[0152]

20 Since a rate of etching is different depending on a glass material of the glass substrate used in each experiment example, a preliminary test was performed so that an etching amount becomes 5 μm , and the etching time was adjusted. When performing the etching as described above, since the glass substrate was dipped in the etching solution, the amount removed by the etching when adjusting the etching time by the
25 preliminary test was calculated from a change of the outer diameters of the glass substrate before and after the etching.

[0153]

As described above, the etching time was different depending on a glass material of a glass substrate, but the etching time was in a range of 1 minute to 20 minutes.

5 [0154]

Herein, a change of states of the surface of the outer peripheral side surface part before and after the etching will be described with reference to Fig. 3 and Fig. 4. Images when the states of the surface before and after etching the outer peripheral side surface part of the glass substrate are enlarged by the laser microscope described above and observed, are shown in Fig. 3(A) and Fig. 3(B) for Experiment Example 1 which
10 will be described later, and in Fig. 4(A) and Fig. 4(B) for Experiment Example 10 which will be described later. In both cases, “(A)” shows the state before the etching and “(B)” shows the state after the etching. As clearly shown with the comparison between Fig. 3(A) and Fig. 4(A), and the comparison between Fig. 3(B) and Fig. 4(B),
15 respectively, opening parts (pits) 31 and 32 of micro cracks which could not be observed before etching becomes larger due to etching and clear opening parts can be confirmed.

(2) Heat Cracking Test

Regarding glass substrates prepared in each experiment example, a generation
20 ratio of heat cracking was evaluated by applying a rapid temperature change thereto.

[0155]

The glass substrates prepared in each experiment example were heated to 230°C in an electric furnace and were extracted from the electric furnace without cooling. The glass substrate was moved in water in a water tank filled with water so
25 that a water temperature was 20°C and a depth was 10 mm, in advance, in a direction parallel to the main surface of the glass substrate, that is, the glass substrate was put

therein while maintaining a state where the water surface and the main surface of the glass substrate were perpendicular to each other.

[0156]

When putting the glass substrate into water, in a case where a crack having a
5 length of 5 mm or larger was generated from an outer peripheral part in the glass substrate, it was determined that heat cracking occurred.

[0157]

In each experiment example, 100 glass substrates were tested, and a ratio of the glass substrates determined that heat cracking occurred among the 100 tested glass
10 substrates was defined as a heat cracking ratio.

[0158]

In a heat cracking test, after heating the glass substrate to 230°C as described above, the glass substrate was put into water having a water temperature of 20°C within 3 seconds. Accordingly, a rapid temperature change at approximately 70°C/sec was
15 applied to the glass substrate. In a step of manufacturing the energy-assisted magnetic recording medium, a temperature change is applied at approximately 65°C/sec, for example. Accordingly, this test shows that, as long as a glass substrate has a sufficiently low heat cracking ratio when a temperature change at 70°C/sec is applied as described above, such a glass substrate can also be suitably used for use application in
20 which a rapid temperature change is applied, such as the glass substrate for the energy-assisted magnetic recording medium.

[0159]

As the glass substrate used in the heat cracking test and the glass substrates used for evaluation of the arithmetic average roughness Ra and the maximum height
25 roughness Rz of the etched outer peripheral side surface part, the substrates manufactured under the same conditions were used in each experiment example, but the

substrates were not the same. This is because, when etching is performed for measuring the arithmetic average roughness Ra and the maximum height roughness Rz of the etched outer peripheral side surface part, since the width R of the tip of the micro crack of the outer peripheral side surface part becomes large, an extension of crack due to heat stress does not occur, and cracking is not generated. That is, in the heat cracking test, the glass substrate which has not been etched was used.

[0160]

Next, a manufacturing method of the glass substrate for a magnetic recording medium of each experiment example will be described. Experiment Example 1 to Experiment Example 3, Experiment Example 5, Experiment Example 6, Experiment Example 10 to Experiment Example 16, Experiment Example 19 and Experiment Example 21 are working examples, and Experiment Example 7, Experiment Example 8, Experiment Example 17, Experiment Example 18, Experiment Example 20, and Experiment Example 22 are comparative examples. Experiment Example 4 and Experiment Example 9 are reference examples.

[Experiment Example 1]

The glass substrate for a magnetic recording medium was manufactured by performing each step in the following order.

(Shape-processing step)

A glass sheet formed of a glass A in Table 1 was processed into a glass substrate having a doughnut shape having a circular hole at the center part thereof, so as to obtain a glass substrate for a magnetic recording medium having an outer diameter of 65 mm, an inner diameter of 20 mm, and a thickness of 0.8 mm.

[0161]

Incidentally, the inner diameter means a diameter of the center cored part.

(Chamfering Step)

The inner peripheral chamfered parts and the outer peripheral chamfered parts were respectively formed in the inner peripheral edge and the outer peripheral edge of the glass substrate obtained in the shape-processing step. At that time, regarding each chamfered part, chamfering process was performed so as to obtain a glass substrate
5 having a chamfering width of 0.15 mm and a chamfering angle of 45°.

[0162]

In the chamfering process, the inner peripheral edge and the outer peripheral edge were simultaneously ground while supplying a grinding lubricant containing a surfactant to a grinding point by using a chamfering machine including a diamond
10 wheel, whereby the inner peripheral chamfered parts and the outer peripheral chamfered parts were formed.

[0163]

In Experiment Examples 1 and 2, after performing grinding with an electrodeposition type diamond #500, the finish grinding was performed with respect to
15 50 μm of the surface by using a resin bond type diamond #600.

[0164]

In Experiment Examples 3 to 22 which will be described later, the grinding was performed by using only the electrodeposition type diamond #500.

(Main Surface Polishing Step: Primary Lapping Step)

20 The upper and lower main surfaces of the glass substrate were lapped by using a double side polishing machine (product name: 16BF manufactured by Hamai Co., Ltd.) with a fixed abrasive tool containing diamond particles having an average particle diameter of 9 μm as a polishing tool and a lapping fluid containing a surfactant. As a carrier for holding the glass substrate in the double side polishing machine, a carrier
25 formed of a glass fiber-containing epoxy resin was used.

[0165]

After completing the main surface polishing step (primary lapping step), the glass substrate was cleaned and the lapping fluid and other contamination were removed.

[0166]

- 5 The average particle diameter means a diameter at which an integrated value based on volume is 50% in particle size distribution acquired by using a laser diffraction and scattering method. In other parts of this specification, the average particle diameter has the same meaning.

(Edge Polishing Step)

- 10 The glass substrates manufactured under the same conditions up to the main surface polishing step (primary lapping step) were stacked on each other. A nylon brush was used as a polishing tool, and the inner peripheral edges and the outer peripheral edges of the stacked glass substrates were polished by pressing the brush, which was rotated, to the inner peripheral edges and the outer peripheral edges thereof,
15 while supplying a polishing slurry containing cerium oxide having an average particle diameter of 1 μm .

[0167]

- A removal amount of the outer peripheral edge at that time was set to 50 μm and a removal amount of the inner peripheral edge was set to 25 μm . The removal
20 amount of the inner and outer peripheral edges indicates a changed amount of the outer diameter or the inner diameter of the substrate. That is, the machining allowance of the one side is the half thereof. For example, the removal amount of 10 μm indicates that 5 μm of one side is polished.

(Main Surface Polishing Step: Secondary Lapping Step)

- 25 The upper and lower main surfaces of the glass substrate were lapped by using a double side polishing machine (product name: 16BF manufactured by Hamai Co.,

Ltd.) with a fixed abrasive tool containing diamond particles having an average particle diameter of 4 μm as a polishing tool and a lapping fluid containing a surfactant.

[0168]

As a carrier for holding the glass substrate in the double side polishing machine,
5 a carrier formed of a glass fiber-containing epoxy resin was used.

[0169]

After completing the main surface polishing step (secondary lapping step), the glass substrate was cleaned and the lapping fluid and other contamination were removed.

10 (Main Surface Polishing Step: Primary Polishing Step)

The upper and lower main surfaces of the glass substrate were polished by using a double side polishing machine (product name: 16BF manufactured by Hamai Co., Ltd.) with a suede type polyurethane polishing pad as a polishing tool and a polishing slurry containing cerium oxide having an average particle diameter of 1 μm .

15 [0170]

In the main surface polishing step (primary polishing step), an amount removed by the polishing was 25 μm . The polishing time was, for example, 50 minutes. The removal amount at the time of the main surface polishing indicates a changed amount of a thickness of the substrate. That is, the machining allowance of the one side is the
20 half thereof. For example, the removal amount of 10 μm indicates that 5 μm of one side is polished.

[0171]

As a carrier for holding the glass substrate in the double side polishing machine, a carrier formed of a glass fiber-containing epoxy resin was used.

25 [0172]

After completing the main surface polishing step (primary polishing step), the glass substrate was cleaned and the polishing slurry and other contamination were removed.

(Main Surface Polishing Step: Secondary Polishing Step)

5 The upper and lower main surfaces of the glass substrate were polished by using a double side polishing machine (product name: 16BF manufactured by Hamai Co., Ltd.) with a suede type polyurethane polishing pad as a polishing tool and a polishing slurry containing colloidal silica having an average particle diameter of 20 nm or smaller.

10 [0173]

In the main surface polishing step (secondary polishing step), an amount removed by the polishing was 1 μm . The polishing time was, for example, 30 minutes.

[0174]

15 As a carrier for holding the glass substrate in the double side polishing machine, a carrier formed of an aramid fiber-containing epoxy resin was used.

[0175]

After completing the main surface polishing step (secondary polishing step), the glass substrate was cleaned and the polishing slurry and other contamination were removed.

20 (Cleaning and Drying Step)

The glass substrate after performing the main surface polishing step (secondary polishing step) was cleaned (precise cleaning) in the order of scrub cleaning, ultrasonic cleaning in a state of being dipped in a detergent solution, and ultrasonic cleaning in a state of being dipped in pure water, and was then dried with isopropyl alcohol vapor.

25 [0176]

Regarding the glass substrate for a magnetic recording medium obtained by performing the above procedure, the arithmetic average roughness Ra of the outer peripheral side surface part, the arithmetic average roughness Ra of the etched outer peripheral side surface part, and the maximum height roughness Rz of the etched outer peripheral side surface part were evaluated and the heat cracking test was performed. The evaluation results are shown in Table 2.

[Experiment Example 2]

The glass substrate was manufactured and evaluated in the same manner as in Experiment Example 1, except for setting the removal amount of the outer peripheral polishing in the edge polishing step to 11 μm . The evaluation results are shown in Table 2.

[Experiment Example 3 to Experiment Example 6]

The glass substrate was manufactured and evaluated in the same manner as in Experiment Example 1, except for the following points.

(Changed Point 1)

The order of steps from the main surface polishing step (primary lapping step) to the main surface polishing step (secondary polishing step) was changed as the following order.

[0177]

In Experiment Example 3 to Experiment Example 6, after the main surface polishing step (primary lapping step), the main surface polishing step (secondary lapping step), the main surface polishing step (primary polishing step), the edge polishing step, the main surface polishing step (secondary polishing step) were performed in this order.

(Changed Point 2)

The material of the carrier used in the main surface polishing step (primary lapping step), the main surface polishing step (secondary lapping step), main surface polishing step (primary polishing step), and the main surface polishing step (secondary polishing step) was changed.

5 [0178]

Specifically, a stainless steel carrier was used in Experiment Example 3. A glass fiber-containing epoxy resin carrier was used in Experiment Example 4, an aramid fiber-containing epoxy resin carrier was used in Experiment Example 5, and a polyvinyl chloride resin carrier was used in Experiment Example 6.

10 [0179]

The conditions in each step were the same as in the case of Experiment Example 1, except for the different material of the carrier used in each main surface polishing step.

[0180]

15 The evaluation results are shown in Table 2.

[Experiment Example 7 to Experiment Example 15]

The glass substrate was manufactured and evaluated in the same manner as in Experiment Example 1, except for the following points.

(Changed Point 1)

20 The order of steps from the main surface polishing step (primary lapping step) to the main surface polishing step (secondary polishing step) was changed as the following order.

[0181]

25 After the main surface polishing step (primary lapping step), the main surface polishing step (secondary lapping step), the main surface polishing step (primary polishing step), the main surface polishing step (secondary polishing step), and the edge

polishing step were performed in this order. In Experiment Example 7, the edge polishing step was not performed.

(Changed Point 2)

The conditions of the edge polishing step were changed as follows.

5 [0182]

In Experiment Example 7, the edge polishing step was not performed. The removal amounts of the outer peripheral polishing in the edge polishing step in Experiment Example 8 to Experiment Example 15 were set to 5 μm (Experiment Example 8), 8 μm (Experiment Example 9), 11 μm (Experiment Example 10), 16 μm (Experiment Example 11), 21 μm (Experiment Example 12), 27 μm (Experiment Example 13), 32 μm (Experiment Example 14), and 38 μm (Experiment Example 15), respectively.

(Changed Point 3)

15 The material of the carrier used in the main surface polishing step (primary lapping step), the main surface polishing step (secondary lapping step), main surface polishing step (primary polishing step), and the main surface polishing step (secondary polishing step) was changed.

[0183]

20 A glass fiber-containing epoxy resin carrier was used in Experiment Example 7, and an aramid fiber-containing epoxy resin carrier was used in Experiment Examples 8 to 15.

[0184]

The conditions in each step were the same as in the case of Experiment Example 1, except for the above points.

25 [0185]

The evaluation results are shown in Table 2.

[Experiment Example 16]

In this experiment example, the glass substrate was manufactured and evaluated in the same manner as in Experiment Example 1, except for performing a chemical strengthening step of performing a chemical strengthening treatment of the glass substrate, after the main surface polishing step (primary polishing step) and before the main surface polishing step (secondary polishing step). The evaluation results are shown in Table 2.

[0186]

The chemical strengthening was performed by dipping the glass substrate after the main surface polishing step (primary polishing step) into a dissolved salt containing 60 wt% of potassium nitrate and 40 wt% of sodium nitrate and having a temperature of 400°C.

[0187]

A process of preheating the glass substrate at 350°C for 30 minutes was provided before dipping the glass substrate into the dissolved salt. After dipping the glass substrate into the dissolved salt, the glass substrate was left at 350°C for 10 minutes to perform a process of causing the dissolved salt to flow down, followed by gradually cooling.

[0188]

The chemical strengthening step was performed so that a compressive stress depth DOL of the outer peripheral side surface part is 10 μm.

[Experiment Example 17 and Experiment Example 18]

In this experiment example, the glass substrate was manufactured and evaluated in the same manner as in Experiment Example 16, except for setting the removal amount of the outer peripheral polishing in the edge polishing step to 5 μm and performing the chemical strengthening so that a compressive stress depth DOL of the

outer peripheral side surface part in the chemical strengthening step is 10 μm in Experiment Example 17, and 17 μm in Experiment Example 18.

[0189]

The evaluation results are shown in Table 2.

5 [Experiment Example 19 and Experiment Example 21]

The glass substrate was manufactured and evaluated in the same manner as in Experiment Example 1, except for using a glass sheet formed of a glass B (Experiment Example 19) and a glass C (Experiment Example 21) in Table 1 as the glass substrate to be provided in the shape-processing step. The evaluation results are shown in Table 2.

10 [Experiment Example 20 and Experiment Example 22]

The glass substrate was manufactured and evaluated in the same manner as in Experiment Example 8, except for using a glass sheet formed of a glass B (Experiment Example 20) and a glass C (Experiment Example 22) in Table 1 as the glass substrate to be provided in the shape-processing step. The evaluation results are shown in Table 2.

15

[0190]

Table 1

		Glass A	Glass B	Glass C
Composition (mol%)	SiO ₂	64	65	66
	Al ₂ O ₃	9	11	11
	B ₂ O ₃	0	0	8
	Li ₂ O	3.5	13	0
	Na ₂ O	2.5	6	0
	K ₂ O	4	3	0
	MgO	7	0	5
	CaO	3	0	5
	SrO	0	0	5
	BaO	0	0	0
	ZrO ₂	2	2	0
	TiO ₂	5	0	0
Glass transition point T _g (°C)		652	530	720
Thermal expansion coefficient CTE at 50°C to 350°C ($\times 10^{-7}/^{\circ}\text{C}$)		65	91	38

Table 2

	Glass material				Glass substrate				
	Kind of glass material	Glass transition point Tg (°C)	Thermal expansion coefficient CTE at 50°C to 350°C ($\times 10^{-7}/^{\circ}\text{C}$)	Compressive stress depth DOL (μm)	Properties of outer peripheral side surface part before etching (μm)		Properties of outer peripheral side surface part after etching (μm)		Heat cracking ratio (%)
					Maximum height roughness Rz	Arithmetic average roughness Ra	Maximum height roughness Rz	Arithmetic average roughness Ra	
Experiment Example 1	Glass A	652	65	0	2	0.02	3.4	0.16	2
Experiment Example 2	Glass A	652	65	0	2	0.02	7	0.35	6
Experiment Example 3	Glass A	652	65	0	0.8	0.03	9.7	0.14	8
Experiment Example 4	Glass A	652	65	0	1.7	0.05	10.4	0.32	9
Experiment Example 5	Glass A	652	65	0	0.5	0.03	1.4	0.04	0
Experiment Example 6	Glass A	652	65	0	1	0.04	1.2	0.03	0
Experiment Example 7	Glass A	652	65	0	9.5	0.56	16.8	0.91	33
Experiment Example 8	Glass A	652	65	0	4.2	0.12	14.5	0.61	21
Experiment Example 9	Glass A	652	65	0	3.5	0.09	14	0.4	10
Experiment Example 10	Glass A	652	65	0	1.2	0.04	5	0.14	4
Experiment Example 11	Glass A	652	65	0	1	0.04	3.1	0.11	2

Table 2 (continued)

	Glass material				Glass substrate				
	Kind of glass material	Glass transition point Tg (°C)	Thermal expansion coefficient CTE at 50°C to 350°C ($\times 10^{-7}/^{\circ}\text{C}$)	Compressive stress depth DOL (μm)	Properties of outer peripheral side surface part before etching (μm)		Properties of outer peripheral side surface part after etching (μm)		Heat cracking ratio (%)
					Maximum height roughness Rz	Arithmetic average roughness Ra	Maximum height roughness Rz	Arithmetic average roughness Ra	
Experiment Example 12	Glass A	652	65	0	0.5	0.04	1.3	0.06	1
Experiment Example 13	Glass A	652	65	0	0.9	0.04	0.7	0.03	1
Experiment Example 14	Glass A	652	65	0	0.8	0.04	2.5	0.06	0
Experiment Example 15	Glass A	652	65	0	0.9	0.04	1.2	0.06	0
Experiment Example 16	Glass A	652	65	10	2	0.04	3.2	0.18	0
Experiment Example 17	Glass A	652	65	10	4.2	0.12	13.5	0.58	7
Experiment Example 18	Glass A	652	65	17	4.2	0.12	12.6	0.55	2
Experiment Example 19	Glass B	530	91	0	2	0.02	3.4	0.15	6
Experiment Example 20	Glass B	530	91	0	4.2	0.12	14.3	0.62	25
Experiment Example 21	Glass C	720	38	0	2	0.02	3.3	0.12	0
Experiment Example 22	Glass C	720	38	0	4.2	0.12	13.9	0.55	8

[0192]

Table 3 shows the order of the step when manufacturing the glass substrate in each experiment example. In the same manner as described above, in each experiment example, Step 1 to Step 9 in Table 3 were performed in this order.

Table 3

	Order of steps									Material of carrier in main surface polishing step (secondary polishing step)
	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8	Step 9	
Experiment Example 1	Shape-processing step	Chamfering step	Main surface polishing step (primary lapping step)	edge polishing step (removal amount: 50 μm)	Main surface polishing step (secondary lapping step)	Main surface polishing step (primary polishing step)	-	Main surface polishing step (secondary polishing step)	Cleaning and drying step	Aramid fiber-containing epoxy resin
Experiment Example 2	Shape-processing step	Chamfering step	Main surface polishing step (primary lapping step)	edge polishing step (removal amount: 11 μm)	Main surface polishing step (secondary lapping step)	Main surface polishing step (primary polishing step)	-	Main surface polishing step (secondary polishing step)	Cleaning and drying step	Aramid fiber-containing epoxy resin
Experiment Example 3	Shape-processing step	Chamfering step	Main surface polishing step (primary lapping step)	Main surface polishing step (secondary lapping step)	Main surface polishing step (primary polishing step)	Edge polishing step (removal amount: 50 μm)	-	Main surface polishing step (secondary polishing step)	Cleaning and drying step	Stainless steel
Experiment Example 4	Shape-processing step	Chamfering step	Main surface polishing step (primary lapping step)	Main surface polishing step (secondary lapping step)	Main surface polishing step (primary polishing step)	Edge polishing step (removal amount: 50 μm)	-	Main surface polishing step (secondary polishing step)	Cleaning and drying step	Glass fiber-containing epoxy resin
Experiment Example 5	Shape-processing step	Chamfering step	Main surface polishing step (primary lapping step)	Main surface polishing step (secondary lapping step)	Main surface polishing step (primary polishing step)	Edge polishing step (removal amount: 50 μm)	-	Main surface polishing step (secondary polishing step)	Cleaning and drying step	Aramid fiber-containing epoxy resin
Experiment Example 6	Shape-processing step	Chamfering step	Main surface polishing step (primary lapping step)	Main surface polishing step (secondary lapping step)	Main surface polishing step (primary polishing step)	Edge polishing step (removal amount: 50 μm)	-	Main surface polishing step (secondary polishing step)	Cleaning and drying step	Polyvinyl chloride resin

Table 3 (continued)

	Order of steps									Material of carrier in main surface polishing step (secondary polishing step)
	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8	Step 9	
Experiment Example 7	Shape-processing step	Chamfering step	Main surface polishing step (primary lapping step)	Main surface polishing step (secondary lapping step)	Main surface polishing step (primary polishing step)	Main surface polishing step (secondary polishing step)	-	No edge polishing step (removal amount: 5 μm)	Cleaning and drying step	Glass fiber-containing epoxy resin
Experiment Example 8	Shape-processing step	Chamfering step	Main surface polishing step (primary lapping step)	Main surface polishing step (secondary lapping step)	Main surface polishing step (primary polishing step)	Main surface polishing step (secondary polishing step)	-	Edge polishing step (removal amount: 5 μm)	Cleaning and drying step	Aramid fiber-containing epoxy resin
Experiment Example 9	Shape-processing step	Chamfering step	Main surface polishing step (primary lapping step)	Main surface polishing step (secondary lapping step)	Main surface polishing step (primary polishing step)	Main surface polishing step (secondary polishing step)	-	Edge polishing step (removal amount: 8 μm)	Cleaning and drying step	Aramid fiber-containing epoxy resin
Experiment Example 10	Shape-processing step	Chamfering step	Main surface polishing step (primary lapping step)	Main surface polishing step (secondary lapping step)	Main surface polishing step (primary polishing step)	Main surface polishing step (secondary polishing step)	-	Edge polishing step (removal amount: 11 μm)	Cleaning and drying step	Aramid fiber-containing epoxy resin
Experiment Example 11	Shape-processing step	Chamfering step	Main surface polishing step (primary lapping step)	Main surface polishing step (secondary lapping step)	Main surface polishing step (primary polishing step)	Main surface polishing step (secondary polishing step)	-	Edge polishing step (removal amount: 16 μm)	Cleaning and drying step	Aramid fiber-containing epoxy resin
Experiment Example 12	Shape-processing step	Chamfering step	Main surface polishing step (primary lapping step)	Main surface polishing step (secondary lapping step)	Main surface polishing step (primary polishing step)	Main surface polishing step (secondary polishing step)	-	Edge polishing step (removal amount: 21 μm)	Cleaning and drying step	Aramid fiber-containing epoxy resin
Experiment Example 13	Shape-processing step	Chamfering step	Main surface polishing step (primary lapping step)	Main surface polishing step (secondary lapping step)	Main surface polishing step (primary polishing step)	Main surface polishing step (secondary polishing step)	-	Edge polishing step (removal amount: 27 μm)	Cleaning and drying step	Aramid fiber-containing epoxy resin

Table 3 (continued)

	Order of steps									Material of carrier in main surface polishing step (secondary polishing step)
	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8	Step 9	
Experiment Example 14	Shape-processing step	Chamfering step	Main surface polishing step (primary lapping step)	Main surface polishing step (secondary lapping step)	Main surface polishing step (primary polishing step)	Main surface polishing step (secondary polishing step)	-	Edge polishing step (removal amount: 32 μm)	Cleaning and drying step	Aramid fiber-containing epoxy resin
Experiment Example 15	Shape-processing step	Chamfering step	Main surface polishing step (primary lapping step)	Main surface polishing step (secondary lapping step)	Main surface polishing step (primary polishing step)	Main surface polishing step (secondary polishing step)	-	Edge polishing step (removal amount: 38 μm)	Cleaning and drying step	Aramid fiber-containing epoxy resin
Experiment Example 16	Shape-processing step	Chamfering step	Main surface polishing step (primary lapping step)	edge polishing step (removal amount: 50 μm)	Main surface polishing step (secondary lapping step)	Main surface polishing step (primary polishing step)	Chemical strengthening step	Main surface polishing step (secondary polishing step)	Cleaning and drying step	Aramid fiber-containing epoxy resin
Experiment Example 17	Shape-processing step	Chamfering step	Main surface polishing step (primary lapping step)	edge polishing step (removal amount: 5 μm)	Main surface polishing step (secondary lapping step)	Main surface polishing step (primary polishing step)	Chemical strengthening step	Main surface polishing step (secondary polishing step)	Cleaning and drying step	Aramid fiber-containing epoxy resin
Experiment Example 18	Shape-processing step	Chamfering step	Main surface polishing step (primary lapping step)	edge polishing step (removal amount: 5 μm)	Main surface polishing step (secondary lapping step)	Main surface polishing step (primary polishing step)	Chemical strengthening step	Main surface polishing step (secondary polishing step)	Cleaning and drying step	Aramid fiber-containing epoxy resin
Experiment Example 19	Shape-processing step	Chamfering step	Main surface polishing step (primary lapping step)	edge polishing step (removal amount: 50 μm)	Main surface polishing step (secondary lapping step)	Main surface polishing step (primary polishing step)	-	Main surface polishing step (secondary polishing step)	Cleaning and drying step	Aramid fiber-containing epoxy resin
Experiment Example 20	Shape-processing step	Chamfering step	Main surface polishing step (primary lapping step)	Main surface polishing step (secondary lapping step)	Main surface polishing step (primary polishing step)	Main surface polishing step (secondary polishing step)	-	Edge polishing step (removal amount: 5 μm)	Cleaning and drying step	Aramid fiber-containing epoxy resin

Table 3 (continued)

	Order of steps									Material of carrier in main surface polishing step (secondary polishing step)
	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8	Step 9	
Experiment Example 21	Shape-processing step	Chamfering step	Main surface polishing step (primary lapping step)	edge polishing step (removal amount: 50 μm)	Main surface polishing step (secondary lapping step)	Main surface polishing step (primary polishing step)	-	Main surface polishing step (secondary polishing step)	Cleaning and drying step	Aramid fiber-containing epoxy resin
Experiment Example 22	Shape-processing step	Chamfering step	Main surface polishing step (primary lapping step)	Main surface polishing step (secondary lapping step)	Main surface polishing step (primary polishing step)	Main surface polishing step (secondary polishing step)	-	Edge polishing step (removal amount: 5 μm)	Cleaning and drying step	Aramid fiber-containing epoxy resin

[0194]

According to the results shown in Table 2, in the glass substrates of Experiment Example 1 to Experiment Example 6, Experiment Example 9 to Experiment Example 16, Experiment Example 19 and Experiment Example 21 in which the arithmetic average roughness Ra of the outer peripheral side surface part is 0.1 μm or smaller and the arithmetic average roughness Ra of the etched outer peripheral side surface part after etching 5 μm of the outer peripheral side surface part from the surface thereof is 0.5 μm or smaller, it was confirmed that the heat cracking ratio was 20% or smaller. This may be because, in the glass substrate having the arithmetic average roughness Ra of the etched outer peripheral side surface part of 0.5 μm or smaller, since an existence frequency of a micro crack of the outer peripheral side surface part is sufficiently low, it is possible to prevent the occurrence of heat cracking even in a case where a rapid temperature change is applied.

[0195]

Meanwhile, it was confirmed that the heat cracking ratio exceeded 20% in the glass substrates of Experiment Examples 7, 8, and 20 in which the arithmetic average roughness Ra of the outer peripheral side surface part is greater than 0.1 μm and the arithmetic average roughness Ra of the etched outer peripheral side surface part obtained after etching 5 μm of the outer peripheral side surface part from the surface thereof is greater than 0.5 μm .

[0196]

This may be because, in the glass substrate of Experiment Examples 7, 8, and 20, since an existence frequency of a micro crack of the outer peripheral side surface part is high, stress is concentrated to the micro crack in a case where a rapid temperature change is applied, thereby generating the heat cracking.

[0197]

In a case where the compressive stress depth DOL is 15 μm or larger as in Experiment Example 18, even when the arithmetic average roughness Ra of the etched outer peripheral side surface part is greater than 0.5 μm , the heat cracking ratio is low. However, DOL of the glass substrate for the energy-assisted magnetic recording medium is preferably 15 μm or smaller, as described above. When Experiment Example 17 in which DOL is 10 μm is compared with Experiment Example 8 having the equivalent arithmetic average roughness Ra, the heat cracking ratio is decreased. However, it is possible to more effectively decrease the heat cracking ratio in Experiment Example 16 in which the arithmetic average roughness Ra of the etched outer peripheral side surface part is lower than 0.5 μm . That is, even in the glass substrate subjected to the chemical strengthening, setting the arithmetic average roughness Ra of the etched outer peripheral side surface part to be 0.5 μm or smaller is effective for decreasing the heat cracking ratio.

[0198]

In Experiment Example 22, since a glass material having a low thermal expansion ratio was used, the generation ratio of heat cracking was lower than that of Experiment Example 8 having the equivalent arithmetic average roughness Ra. However, the heat cracking ratio was further decreased in Experiment Example 21 in which the arithmetic average roughness Ra was low but the same glass material was used. That is, even in a case of using a glass material having a low thermal expansion ratio, setting the arithmetic average roughness Ra of the etched outer peripheral side surface part to be 0.5 μm or smaller is effective for decreasing the heat cracking ratio.

[0199]

When comparing Experiment Example 1 to Experiment Example 4 to each other, it can be confirmed that there is substantially no difference in arithmetic average roughness Ra of the outer peripheral side surface part before the etching, but there are

clear differences in the arithmetic average roughness Ra of the outer peripheral side surface part after the etching, and the heat cracking ratio changes in accordance thereto. Therefore, it is found that the influence on the heat cracking can be evaluated after performing the etching.

5 [0200]

When comparing Experiment Example 2 and Experiment Example 9 to each other, the arithmetic average roughness Ra of the outer peripheral side surface part after the etching is equivalent to each other, but the maximum height roughness Rz of the outer peripheral side surface part after the etching is different from each other. It is confirmed that the generation ratio of the heat cracking also changes in accordance thereto.

[0201]

From the above results, it is confirmed that, it is important to set the arithmetic average roughness Ra of the outer peripheral side surface part after the etching to be 0.5 μm or smaller for the heat cracking ratio, but it is also important to set the maximum height roughness Rz of the outer peripheral side surface part after the etching to be 10 μm or smaller.

[0202]

Herein, a roughness percentage when a load factor is 50% which is used as a method of expressing the surface state is shown in Table 4 as a part of the experiment example. Table 4 also shows the heat cracking ratio shown in Table 3.

[0203]

Table 4

	Roughness percentage when load factor is 50%	Heat cracking ratio (%)
Experiment Example 3	48	8
Experiment Example 4	30	9
Experiment Example 5	62	0
Experiment Example 6	42	0
Experiment Example 7	57	33
Experiment Example 8	67	21
Experiment Example 10	20	4
Experiment Example 11	52	2
Experiment Example 12	33	1
Experiment Example 13	30	1
Experiment Example 14	64	0
Experiment Example 15	38	0

[0204]

The roughness percentage when a load factor is 50% will be briefly described.

5

[0205]

In a measurement result of a surface shape in a region near a surface of a measured object, the region near the surface of the measured object is cut by a plane parallel to a plane forming a macroscopic shape of the surface of the measured object.

[0206]

10

In this case, a level of a height of the region near the surface for performing cutting by a plane coming into contact with a maximum protrusion portion which is

protruded at the maximum is set as a maximum height of 0%, and a level of a height of the region near the surface for performing cutting by a plane coming into contact with a deepest recess which is recessed at the most is set as a minimum height of 100%. The roughness percentage is obtained by expressing the level of cutting height between the maximum height and the minimum height as a percent.

[0207]

The load factor is obtained by dividing an area of a region present on the cut plane of a measured sample in a case where the region is cut at a specific roughness percentage level, by an area of a region present on the cut plane of the measured sample in a case where the region is cut at the roughness percentage of 100%.

[0208]

Accordingly, the roughness percentage when the load factor is 50% shows a level of the cutting height at which the load factor is 50%. That is, in the results shown in Table 4, in the same manner as in the measurement of the arithmetic average roughness Ra, the glass substrate subjected to the etching of 5 μm is measured in a measurement region having a size of 200 $\mu\text{m} \times 200 \mu\text{m}$, and the roughness percentage when a ratio of the area of the region where a measured object is present to the entire measurement region is 50%, is shown.

[0209]

As is clear from the results of Table 4, there is no correlation between the heat cracking ratio and the roughness percentage when the load factor is 50%, and it is confirmed that the roughness percentage is not suitable as an index used when decreasing the cracking generation ratio.

[0210]

The present invention has been specifically described using specific embodiments, but it is clear for a person skilled in the art that various modifications and

changes can be performed without departing from a gist and scope of the invention. The present application is based on Japanese Patent Application No. 2015-257144 filed on December 28, 2015, the contents of which are incorporated herein by reference.

5 DESCRIPTION OF REFERENCE NUMERALS AND SIGNS

[0211]

	10	GLASS SUBSTRATE FOR MAGNETIC RECORDING MEDIUM (GLASS SUBSTRATE)
	121, 122	MAIN SURFACE
10	13	OUTER PERIPHERAL EDGE
	131, 133	OUTER PERIPHERAL CHAMFERED PART
	132	OUTER PERIPHERAL SIDE SURFACE PART
	14	INNER PERIPHERAL EDGE
	141, 143	INNER PERIPHERAL CHAMFERED PART
15	142	INNER PERIPHERAL SIDE SURFACE PART

CLAIMS

[Claim 1]

A glass substrate for a magnetic recording medium, having a doughnut shape and comprising:

a pair of main surfaces;

an outer peripheral edge; and

an inner peripheral edge,

wherein the outer peripheral edge includes an outer peripheral side surface part and a pair of outer peripheral chamfered parts,

an arithmetic average roughness Ra of the outer peripheral side surface part is 0.1 μm or smaller, and

an arithmetic average roughness Ra of an etched outer peripheral side surface part obtained after etching 5 μm of the outer peripheral side surface part from a surface thereof is 0.5 μm or smaller, and a maximum height roughness Rz of the etched outer peripheral side surface part is 10 μm or smaller.

[Claim 2]

The glass substrate for a magnetic recording medium according to claim 1, which is formed of a glass material having a thermal expansion coefficient in a temperature range of 50°C to 350°C of $70 \times 10^{-7}/^{\circ}\text{C}$ or smaller and a glass transition point Tg of 650°C or higher.

[Claim 3]

The glass substrate for a magnetic recording medium according to claim 1 or 2, which is formed of a glass material having a thermal expansion coefficient in a temperature range of 50°C to 350°C of $55 \times 10^{-7}/^{\circ}\text{C}$ or smaller.

[Claim 4]

The glass substrate for a magnetic recording medium according to any one of claims 1 to 3, wherein, at least in the outer peripheral side surface part of the glass substrate, a compressive stress depth DOL obtained by performing a chemical strengthening treatment satisfies $1\ \mu\text{m} \leq \text{DOL} \leq 15\ \mu\text{m}$.

[Claim 5]

The glass substrate for a magnetic recording medium according to any one of claims 1 to 4, which is a glass substrate for a magnetic recording medium, for an energy-assisted magnetic recording medium.

[Claim 6]

A magnetic recording medium comprising the glass substrate for a magnetic recording medium according to any one of claims 1 to 5.