

DESCRIPTION

[Title of Invention]

MAGNETIC-DISK GLASS SUBSTRATE, METHOD FOR MANUFACTURING
5 MAGNETIC-DISK GLASS SUBSTRATE, AND MAGNETIC DISK

[Technical Field]

[0001] The present invention relates to a magnetic-disk glass substrate, a
method for manufacturing a magnetic-disk glass substrate, and a magnetic
10 disk.

[Background Art]

[0002] Conventionally, a glass substrate has been preferably used in a
magnetic disk used as one type of information recording medium. Nowadays,
in order to meet the demand for an increase in the storage capacity of hard disk
15 drive apparatuses, attempts have been made to increase the magnetic
recording density. In recent years, a recording medium for an energy-assisted
magnetic recording method such as a heat-assisted magnetic recording method
in which a magnetic layer of Fe-Pt is formed on a glass substrate in order to
increase the magnetic recording density of a magnetic disk has been proposed.
20 A glass substrate used in an energy-assisted recording medium needs to have a
high glass transition point temperature while maintaining a mechanical
strength as the glass substrate because the glass substrate is subjected to a
high temperature of about 700°C when a magnetic layer of Fe-Pt is formed.

[0003] In one aspect, it is known that in order to increase the mechanical
25 strength, a compressive stress layer is formed on a glass substrate by
performing chemical strengthening processing on the glass substrate. A
compressive stress value of the compressive stress layer and the depth of the
compressive stress layer can be obtained with a Babinet compensator method.
A method for providing a glass substrate having a profile of compressive stress
30 and tensile stress that is suitable for a magnetic-disk glass substrate, based on

the compressive stress value and the depth of compressive stress layer obtained with the Babinet compensator method is also known. For example, there is known to be a chemically strengthened glass substrate in order to obtain a high impact resistance, a main surface of the glass substrate has an outermost
 5 portion stress layer indentation length of 49.1 μm or less, and when an angle between the main surface and compressive stress is θ in the stress profile obtained with the Babinet compensator method, a value y determined by this θ is less than or equal to the outermost portion stress layer indentation length (Patent Literature 1).

Also, a glass substrate for a data storage medium that has excellent impact resistance and a stable disk shape and a method for manufacturing the same are known as well. Specifically, the method for manufacturing the glass substrate includes a chemical strengthening processing step of immersing the glass for the substrate in a molten salt mixture and forming compressive layers
 15 on a front surface and a back surface of glass for a substrate. At this time, the glass for a substrate contains lithium ions as alkaline components, the molten salt mixture contains sodium nitrate, potassium nitrate, and lithium nitrate in an amount of 1 to 6 mass%, and the glass for a substrate is immersed in the molten salt mixture at a processing temperature of 325°C or more and 475°C or
 20 less for 30 minutes or less, and the following equation is satisfied. Note that T indicates a processing temperature (unit: K) and t indicates processing time (unit: seconds). $1900 \leq T \times \log(t^2) \leq 2900$. With this glass substrate, it is also known that mechanical strength can be increased by setting a fracture toughness value measured with an indentation fracture method conforming to
 25 JIS R 1607 to 1.2 or more (Patent Literature 2).

[Citation List]

[Patent Literature]

[0004] [PLT1]: JP 2009-099251A

[PLT2]: JP 2011-134367A

[Summary of Invention]

[Technical Problem]

[0005] However, in general, glass material used for a magnetic-disk glass substrate obtained with the above-described known technique has a glass transition point temperature of 600°C or less, and thus if a conventional magnetic-disk glass substrate is used in the above-described energy-assisted recording medium, the substrate is likely to warp or crack due to being subjected to the above-described high temperature. Thus, the conventional glass substrate cannot be applied to a glass substrate for an energy-assisted recording medium even if the glass substrate has a high mechanical strength at room temperature.

Although reducing the Li_2O content in order to increase the glass transition point temperature is known, a glass substrate made of such glass contains Li in a small amount, and thus even if chemical processing is performed using known chemical strengthening molten salt liquid containing Na, K, and the like, a compressive stress layer having a mechanical strength high enough for a magnetic-disk glass substrate could not be formed in some cases.

[0006] In view of this, an object of the present invention is to provide a magnetic-disk glass substrate that reliably has a mechanical strength suitable for a magnetic disk, a method for manufacturing the magnetic-disk glass substrate, and a magnetic disk in which this magnetic-disk glass substrate is used.

[Solution to Problem]

[0007] (Aspect 1)

25 An aspect of the present invention is a magnetic-disk glass substrate having the following configuration.

The magnetic-disk glass substrate contains

as a glass composition, Li_2O in an amount of 0.1 to 1 mol%,

a fracture toughness value K_{IC} [$\text{MPa} \cdot \text{m}^{1/2}$] is greater than or equal to 1

30 [$\text{MPa} \cdot \text{m}^{1/2}$], and

a compressive stress layer is provided on a surface of the glass substrate by chemical strengthening, a depth D [μm] of the compressive stress layer satisfying $D \geq 57 \cdot K_{IC}^{1.6}$ and $D \geq 20$ [μm].

Note that the fracture toughness value K_{IC} [$\text{MPa} \cdot \text{m}^{1/2}$] is preferably less than or equal to 2.5 [$\text{MPa} \cdot \text{m}^{1/2}$]. Also, the depth D is preferably less than or equal to 150 μm .

[0008] (Aspect 2)

Also, the magnetic-disk glass substrate according to Aspect 1, in which a transition point temperature T_g of the magnetic-disk glass substrate is greater than or equal to 650°C .

[0009] (Aspect 3)

The magnetic-disk glass substrate according to Aspect 1 or 2, containing:

as a glass composition,

15 SiO_2 in an amount of 55 to 78 mol%;

Li_2O in an amount of 0.1 to 1 mol%;

Na_2O in an amount of 2 to 15 mol%; and

MgO , CaO , SrO , and BaO in a total amount of 10 to 25 mol%, in which a molar ratio of a CaO content with respect to a total content of MgO ,

20 CaO , SrO , and BaO ($\text{CaO}/(\text{MgO}+\text{CaO}+\text{SrO}+\text{BaO}))$ is less than or equal to 0.20.

[0010] (Aspect 4)

The magnetic-disk glass substrate according to any one of Aspects 1 to 3, in which a thickness of the magnetic-disk glass substrate is 0.3 to 1.5 mm.

At this time, in the case where the magnetic-disk glass substrate has a nominal size of 2.5 inches or more, the thickness of the magnetic-disk glass substrate is greater than or equal to 0.5 mm.

[0011] (Aspect 5)

The magnetic-disk glass substrate according to any one of Aspects 1 to 4, comprising, as the glass composition of the magnetic-disk glass substrate, aluminosilicate glass that does not contain Ca.

[0012] (Aspect 6)

A magnetic disk including the magnetic-disk glass substrate according to any one of Aspects 1 to 5 and a magnetic layer formed on the surface of the glass substrate.

5 [0013] (Aspect 7)

A method for manufacturing a magnetic-disk glass substrate, including:
processing for producing a disk-shaped glass substrate that contains
 Li_2O in an amount of 0.1 to 1 mol%; and

10 processing for performing chemical strengthening on the glass
substrate such that a fracture toughness value K_{IC} [$\text{MPa} \cdot \text{m}^{1/2}$] is greater than
or equal to 1 [$\text{MPa} \cdot \text{m}^{1/2}$], and a depth D [μm] of a compressive stress layer to be
provided on a surface of the glass substrate by the chemical strengthening
satisfies $D \geq 57 \cdot K_{\text{IC}}^{-1.6}$ and $D \geq 20$ [μm].

[0014] (Aspect 8)

15 The method for manufacturing a magnetic-disk glass substrate
according to Aspect 7, in which the chemical strengthening processing is
processing for immersing the glass substrate in a liquid molten salt mixture
containing KNO_3 and NaNO_3 , and the molten salt mixture contains KNO_3 in an
amount of 55 to 85 mass%.

20 [0015] (Aspect 9)

The method for manufacturing a magnetic-disk glass substrate
according to Aspect 7 or 8, in which

the glass substrate that has undergone the chemical processing
contains:

25 as a glass composition,

SiO_2 in an amount of 55 to 78 mol%;

Li_2O in an amount of 0.1 to 1 mol%;

Na_2O in an amount of 2 to 15 mol%; and

MgO , CaO , SrO , and BaO in a total amount of 10 to 25 mol%, and

30 a molar ratio of a CaO content with respect to a total content of MgO ,

CaO, SrO, and BaO ($\text{CaO}/(\text{MgO}+\text{CaO}+\text{SrO}+\text{BaO})$) is less than or equal to 0.20.

[0016] (Aspect 10)

The method for manufacturing a magnetic-disk glass substrate according to any one of Aspects 7 to 9, in which a thickness of the glass substrate is 0.3 to 1.5 mm.

At this time, the thickness is preferably greater than or equal to 0.5 mm.

[0017] (Aspect 11)

The method for manufacturing a magnetic-disk glass substrate according to any one of Aspects 7 to 10, in which the glass substrate comprises aluminosilicate glass that does not contain Ca.

[Advantageous Effects of the Invention]

[0018] According to the above-described aspects, it is possible to provide a magnetic-disk glass substrate that reliably has a mechanical strength that is suitable for a magnetic disk.

[Brief Description of Drawings]

[0019] FIG. 1 is a perspective view of a magnetic-disk glass substrate of this embodiment.

FIG. 2 is a diagram showing a correspondence relationship between a fracture toughness value and a mechanical strength (flexural strength) before a glass substrate is subjected to damage addition processing.

FIG. 3 is a diagram illustrating a compressive stress layer and a tensile stress layer of a glass substrate of this embodiment.

FIG. 4 is a diagram illustrating a method for testing mechanical strength (flexural strength).

FIG. 5 is a diagram showing a range of a glass substrate of this embodiment.

[Description of Embodiments]

[0020] Hereinafter, a magnetic-disk glass substrate of the present embodiment will be described in detail.

[0021] [Magnetic-disk glass substrate]

FIG. 1 is a perspective view of a magnetic-disk glass substrate 10 (referred to as a glass substrate 10 hereinafter) of the present embodiment. As shown in FIG. 1, the glass substrate 10 has a disk shape, and a central portion thereof is hollowed out in the form of a concentric circle so that the glass substrate has a ring shape. The glass substrate 10 is such that at least a surface of the glass substrate is subjected to chemical strengthening and a compressive stress layer is formed on the surface of the glass plate 10.

The glass substrate 10 contains Li_2O in an amount of 0.1 to 1 mol% as a glass composition. As mechanical characteristics of the glass substrate 10, a fracture toughness value K_{IC} [$\text{MPa} \cdot \text{m}^{1/2}$] is greater than or equal to 1 [$\text{MPa} \cdot \text{m}^{1/2}$]. A compressive stress layer is provided on a surface of the glass substrate 10 by chemical strengthening, and a depth D [μm] of the compressive stress layer satisfies $D \geq 57 \cdot K_{\text{IC}}^{1.6}$ and $D \geq 20$ [μm]. More preferably, the fracture toughness value K_{IC} [$\text{MPa} \cdot \text{m}^{1/2}$] is greater than or equal to 1.2 [$\text{MPa} \cdot \text{m}^{1/2}$], and the depth D [μm] of the compressive stress layer satisfies $D \geq 70 \cdot K_{\text{IC}}^{1.6}$ and $D \geq 35$ [μm].

A glass transition point temperature T_g of glass of such a glass substrate 10 is preferably greater than or equal to 650°C . In this case, the glass substrate 10 can be used as various magnetic-disk glass substrates, but preferably can be used as an energy-assisted magnetic-disk glass substrate.

Note that the fracture toughness value K_{IC} [$\text{MPa} \cdot \text{m}^{1/2}$] is preferably less than or equal to 2.5 [$\text{MPa} \cdot \text{m}^{1/2}$]. Also, the depth D is preferably less than or equal to $150 \mu\text{m}$.

[0022] When a magnetic disk is produced using the glass substrate 10, the magnetic disk is produced by forming at least a magnetic layer on a main surface of the glass substrate 10.

The magnetic layer includes a magnetic material containing an alloy of Fe and/or Co, and Pt as main components, for example. The magnetic disk having this magnetic layer is preferably used as an energy-assisted magnetic

disk. Examples of the magnetic material containing an alloy of Fe and/or Co, and Pt as main components include Fe-Pt based magnetic material, Co-Pt based magnetic material, and Fe-Co-Pt based magnetic material.

[0023] When the above-described magnetic layer is formed, a magnetic material containing an alloy of Fe and/or Co, and Pt as main components is formed on the main surface of the glass substrate, and thereafter annealing processing is performed. Here, usually, the temperature at which a film of the above-described magnetic material is formed is a high temperature that exceeds 500°C. Furthermore, in order that these magnetic materials have the same crystal orientation after film formation, the above-described annealing processing is performed at a temperature exceeding the film formation temperature. Therefore, in the case where the magnetic layer is formed using an Fe-Pt based magnetic material, a Co-Pt based magnetic material, or an Fe-Co-Pt based magnetic material, the glass substrate is subjected to the above-described high temperature. From the viewpoint of having excellent heat resistance, the glass substrate 10 of the present embodiment preferably has a glass transition point temperature of 650°C or more. A preferable lower limit of the glass transition point temperature T_g is 660°C, a more preferable lower limit is 665°C, an even more preferable lower limit is 670°C, and a still more preferable lower limit is 675°C. However, if the glass transition point temperature T_g increases excessively, a chemical strengthening processing temperature, which will be described later, increases, and the surfaces of the glass substrate corrode due to thermal decomposition of the molten salt at the time of chemical strengthening, and thus the upper limit of the glass transition point temperature T_g is preferably set to 740°C. Note that the glass transition point temperature T_g is substantially the same before and after chemical strengthening. The glass substrate 10 made of glass having such a glass transition point temperature T_g has high flatness even after a magnetic layer made of an Fe-Pt based magnetic material, a Co-Pt based magnetic material, or a Fe-Co-Pt based magnetic material is formed on the glass substrate 10 and

annealing processing is performed.

[0024] Making the above-described glass transition point temperature T_g greater than a conventional value can be realized by adjusting the glass composition. Specifically, the glass transition point temperature T_g can be increased by suppressing alkali metal components such as Li and Na.

In this respect, glass used for the glass substrate 10 of the present embodiment contains Li_2O in an amount of 0.1 to 1 mol%. The Li_2O content percentage is preferably 0.1 to 0.6%, and is more preferably 0.1 to 0.3%.

[0025] With regard to the glass substrate having the above-described glass composition, the inventor of the present invention conducted various studies on the formation of a compressive stress layer that meets a mechanical strength required for a magnetic disk, focusing on chemical strengthening processing used in a method for manufacturing the glass substrate.

In general, a known flexural strength is used as the mechanical strength of the magnetic-disk glass substrate. The flexural strength of the magnetic-disk glass substrate is a value defined by a load weight at which the glass substrate fractures when a load is gradually applied to a steel ball that is larger than a circular hole created in the center of the glass substrate and is placed on the above-described circular hole. It can be said that this method of testing flexural strength simulates the mechanical strength of a magnetic-disk glass substrate fixed to a rotatory spindle in a hard disk drive apparatus. On the other hand, conventionally, the fracture toughness value K_{IC} [$\text{MPa} \cdot \text{m}^{1/2}$] measured by an indentation fracture method conforming to JIS R 1607 has been used as an index of the mechanical strength of the glass substrate.

[0026] FIG. 2 shows a correspondence relationship between the above-described fracture toughness value K_{IC} [$\text{MPa} \cdot \text{m}^{1/2}$] and a flexural strength value in a glass substrate in a state in which a brand-new glass substrate produced as a magnetic-disk glass substrate, that is, a glass substrate in a state in which there is no damage on an inner edge surface around the circular hole of the glass substrate and a peripheral portion of the

circular hole, such as those described later. As is clear from FIG. 2, it is understood that the higher the fracture toughness value K_{IC} is, the higher the flexural strength generally is. However, the above-described correspondence relationship results from using a brand-new glass substrate that does not have

5 damage on the inner edge surface around the circular hole of the glass substrate and the peripheral portion of the circular hole on the main surfaces of the glass substrate. There are cases where the inner edge surface around the circular hole provided at the center of the actual magnetic-disk glass substrate and the peripheral portion of the circular hole of the main surfaces of the actual

10 glass substrate are slightly damaged by coming into contact with various members until the glass substrate is fixed to the rotatory spindle of the hard disk drive apparatus. For example, when the glass substrate is subjected to position adjustment while in contact with a rotatory spindle so as to be fixed to the rotatory spindle, or when the glass substrate is removed and checked using

15 a contact sensor, there are cases where the inner edge surface around the circular hole of the glass substrate and the peripheral portion of the circular hole of the main surfaces are damaged. In particular, the next-generation magnetic recording in which the energy-assisted magnetic recording method is used has an extremely high track density, and thus in order to suppress

20 tracking mistake, it is necessary to precisely position a magnetic disk with respect to the spindle. When this adjustment operation is performed, the periphery of the circular hole of the glass substrate is easily damaged. The inventor of the present invention found that there are cases where, as described above, a correspondence relationship such as that shown in FIG.2 is not

25 necessarily established due to damage occurring before the glass substrate is actually incorporated in the hard disk drive apparatus. In such a case, an incidence rate (defect rate) at which the flexural strength decreases is not in an allowable range, and thus the yield of magnetic-disk glass substrates decreases. In particular, the inventor found that the above-described phenomenon is

30 significantly prominent in a glass substrate containing Li_2O in a small amount.

[0027] The inventor of the present invention judged that an index other than the fracture toughness value K_{IC} is needed in the case of failing to establish the above-described correspondence relationship. In view of this, the inventor examined defect rate of glass substrates that cannot be provided as products
 5 and are judged as reject products due to a reduction in flexural strength resulting from the inner edge surfaces of the glass substrates being damaged, while changing the glass compositions of the glass substrates and conditions of chemical processing that is performed on the glass substrates, and conducted intensive studies on indexes that affect the defect rate.

10 As a result, the inventor found that in order to obtain glass substrates that do not warp even when the glass substrates are subjected to a high temperature of about 700°C and that do not crack even when the glass substrates are incorporated in HDDs after various adjustments, defect rate of the glass substrates can be reduced by adjusting processing conditions of
 15 chemical strengthening in glass substrates containing Li_2O in an amount of 0.1 to 1 mol%. Moreover, the inventor found that with the glass substrates that are judged as accepted products in screening using the pass rate (=1-defect rate) of glass substrates, it is necessary that the fracture toughness value K_{IC} is greater than or equal to 1 [$MPa \cdot m^{1/2}$] and the depth of the compressive stress
 20 layer formed on the glass surface by chemical strengthening is greater than or equal to a given value and is greater than a value defined based on the fracture toughness value K_{IC} .

[0028] That is, in the glass substrate 10 made of glass containing Li_2O in an amount of 0.1 to 1 mol%, which is an extremely small amount, the fracture
 25 toughness value K_{IC} [$MPa \cdot m^{1/2}$] is greater than or equal to 1 [$MPa \cdot m^{1/2}$], a compressive stress layer is provided on a surface of the glass substrate by chemical strengthening, the depth D [μm] of the compressive stress layer satisfying $D \geq 57 \cdot K_{IC}^{-1.6}$ and $D \geq 20$ [μm]. In this manner, by defining the fracture toughness value K_{IC} of the glass substrate and the depth D of the
 30 compressive stress layer, the glass substrate reliably has a mechanical strength

suitable for the magnetic disk. Also, the inventor found that when the fracture toughness value K_{IC} and the depth D of the compressive stress layer satisfy the above-described ranges and the Li_2O content is 0.1 to 1 mol%, the glass substrate reliably has a mechanical strength suitable for a magnetic disk.

5 Hereinafter, the fracture toughness value K_{IC} and the depth D of the compressive stress layer will be described.

[0029] (Fracture toughness value K_{IC})

The fracture toughness value K_{IC} [$MPa \cdot m^{1/2}$] can be obtained by pushing a sharp diamond indenter (Vickers indenter) of a known Vickers
10 durometer into a glass substrate at a load P [N] and forming an indentation and a crack on the glass substrate. Letting a Young's modulus of the glass substrate be E [Pa], an indentation diagonal line length be d [m], and half the length of a surface crack be a [m], a fracture toughness value K_{IC} [$MPa \cdot m^{1/2}$] is expressed by the following equation.

15
$$K_{IC} = 0.026 \cdot E^{1/2} \cdot P^{1/2} \cdot (d/2)/a^{3/2}.$$

Note that unless otherwise stated, the fracture toughness value K_{IC} means a fracture toughness value measured with the load P set to 9.81 N (1000 gf). Because the above-described fracture toughness value changes in accordance with the glass composition and chemical strengthening conditions,
20 in order to obtain a chemical strengthened magnetic-disk glass substrate, the above-described fracture toughness value may be set in a desirable range by composition adjustment and chemical strengthening processing conditions.

[0030] (Compressive stress layer)

FIG. 3 is a diagram illustrating a compressive stress layer and a tensile
25 stress layer of the glass substrate 10.

Since the glass substrate 10 of the present embodiment is subjected to chemical strengthening, compressive stress layers 14 are formed on surfaces 12 of the main surfaces - on both sides of the glass substrate 10, and a tensile stress layer 16 is formed inside the glass substrate 10 so as to be sandwiched
30 between the compressive stress layers 14 on both sides. These compressive

stress layers 14 and the tensile stress layer 16 are formed by performing chemical strengthening on the glass substrate 10.

[0031] In general, if chemical strengthening is performed by immersing glass constituting the glass substrate in a molten salt mixture of sodium salt and potassium salt, Li ions in the glass undergo ion exchange with Na ions in the molten salt, and Na ions in the glass undergo ion exchange with K ions in the molten salt, as a result of which the compressive stress layers are formed in the vicinity of the surfaces and the tensile stress layer is formed inside the glass.

However, glass that contains Li_2O in an amount of only 1 mol% or less as the glass composition is used to produce the glass substrate 10 of the present embodiment, and thus the depth D of the compressive stress layer 14 is small and the maximum value of compressive stress is extremely high. In general, in the glass substrate in which glass that contains Li_2O in an amount of more than 1 mol% is used, Li ions in the glass undergo ion exchange with Na ions in the molten salt and Na ions in the glass undergo ion exchange with K ion in the molten salt, as a result of which a smooth stress distribution is formed.

However, as the glass substrate 10 of the present embodiment, glass having a low Li_2O content percentage contains only a small amount of Li ions that undergo ion exchange with Na^+ ions in the molten salt. On the other hand, Na ions in the glass and K ions in the molten salt undergo ion exchange with each other. The larger the ion radius of alkali metal ions in the glass is, the smaller the diffusion velocity of alkali metal ions is, and thus K ions that enter the glass due to ion exchange do not diffuse in the glass and remain on the surface 12 of the glass. Thus, the depth D of the compressive stress layer 14 of the

glass substrate 10 that contains Li_2O in an amount of only 1 mol% or less is shallow. In general, such a compressive stress layer can be measured by a Babinet method. However, with the glass substrate 10 of the present embodiment, the depth D of the compressive stress layer 14 is shallow, whereas the maximum value of compressive stress is significantly large, and thus it is difficult to measure the value.

In the case where the Li_2O content percentage is extremely low, it is difficult to obtain the effect of chemical strengthening, and thus the lower limit of the Li_2O content percentage is 0.1 mol%. A preferable range of the Li_2O content percentage is 0.1 to 0.6 mol%.

5 In the glass substrate 10 of the present embodiment, the depth D of the above-described compressive stress layer 14 satisfies $D \geq 57 \cdot K_{IC}^{-1.6}$ and $D \geq 20$ [μm].

[0032] The glass substrate 10 in which the fracture toughness value K_{IC} and the depth D of the compressive stress layer 14 are defined in this manner can
10 be produced with a method for manufacturing a glass blank for a magnetic disk, which will be described later.

From the viewpoint of ensuring the strength of the glass substrate 10, the thickness of the glass substrate 10 of the present embodiment is preferably 0.3 to 1.5 mm. The thickness is preferably greater than or equal to 0.5 mm.

15 [0033] (Testing and evaluation of mechanical strength of glass substrate)

When the glass substrate 10 is incorporated in a hard disk drive apparatus, the glass substrate 10 is fixed in contact with a rotatory spindle, and thus an inner edge surface of the glass substrate 10 is easily damaged. Also, the position of the glass substrate is adjusted finely until the glass
20 substrate is fixed to the rotatory spindle. In order to record a servo track before the glass substrate is incorporated in the hard disk drive apparatus, the inner edge surface of the glass substrate 10 is fixed to a jig. At this time, the inner edge surface of the glass substrate 10 is easily damaged. Such damage reduces the mechanical strength (flexural strength).

25 FIG. 4 is a diagram illustrating a method for testing mechanical strength (flexural strength). In mechanical strength (flexural strength) testing, a steel ball 18 having a diameter larger than a circular hole created in the center of the glass substrate 10 is placed on the circular hole, and a minimum load weight at which the glass substrate 10 fractures when a load is
30 applied downward to the steel ball 18 is obtained. The glass substrate is

evaluated using this minimum load weight. Such mechanical strength (flexural strength) testing is performed after the rotary spindle is allowed to pass through the inner edge surface of the glass substrate 10 in advance and the glass substrate is disposed at a predetermined position and the processing for removing the glass substrate from a rotatory spindle is sequentially performed, that is, after damage addition processing is performed. Because of this damage addition processing, the state of a glass substrate when incorporated in a hard disk drive apparatus as described above is reproduced in the glass substrate 10.

As is understood from FIG. 2, which shows the correspondence relationship between the fracture toughness value K_{IC} and the mechanical strength (flexural strength) before the above-described damage addition processing is performed on the glass substrate, in the case of the glass substrate 10 that does not have damage on the inner edge surface at all, the fracture toughness value K_{IC} and mechanical strength (flexural strength) relatively correspond to each other. However, with the glass substrate 10 that has damage on the inner edge surface, the correspondence relationship between the fracture toughness value K_{IC} and the mechanical strength (flexural strength) decreases.

Therefore, with the present embodiment, the mechanical strength of the glass substrate on which the above-described damage addition processing has been performed is evaluated.

[0034] Evaluation of the mechanical strength (flexural strength) of such glass substrates were performed on glass substrates 10 of a plurality of conditions that were produced with different glass compositions and different conditions of chemical strengthening processing. The plurality of conditions are classified as follows: a condition that the pass rate of glass substrates whose flexural strength satisfies a condition of being 60 N or more and that are determined as accepted products when the above-described mechanical strength (flexural strength) evaluation is performed, is greater than or equal to 95% is classified

as a condition under which the glass substrate reliably has a mechanical strength suitable for a magnetic disk; and the case where the pass rate is less than 95% is classified as a condition under which the glass substrate has a mechanical strength that is not suitable for a magnetic disk. FIG. 5 is a diagram showing the results of the above-described classification, and is a diagram showing the range of the glass substrate where the pass rate regarding the mechanical strength (flexural strength) is greater than or equal to 95%. In FIG. 5, in the glass substrate containing Li_2O in an amount of 1 mol% or less as the glass composition, the hatched region is the range of the glass substrate where the pass rate is greater than or equal to 95%, that is, the range of the glass substrate that reliably has a mechanical strength (flexural strength) suitable for a magnetic disk. In this hatched region, the fracture toughness value K_{IC} is greater than or equal to 1 [$\text{MPa} \cdot \text{m}^{1/2}$], and the depth D of the compressive stress layer satisfies $D \geq 57 \cdot K_{\text{IC}}^{-1.6}$ and $D \geq 20$ [μm]. That is, a glass substrate whose fracture toughness value K_{IC} [$\text{MPa} \cdot \text{m}^{1/2}$] is greater than or equal to 1 [$\text{MPa} \cdot \text{m}^{1/2}$], in which compressive stress layers are provided on the surfaces of the glass substrate by chemical strengthening, and in which the depth D [μm] of the compressive stress layer satisfies $D \geq 57 \cdot K_{\text{IC}}^{-1.6}$ and $D \geq 20$ [μm], is a glass substrate having a mechanical strength suitable for a magnetic disk. It is more preferable that the fracture toughness value K_{IC} [$\text{MPa} \cdot \text{m}^{1/2}$] is greater than or equal to 1.2 [$\text{MPa} \cdot \text{m}^{1/2}$], and the depth D of the compressive stress layer satisfies $D \geq 70 \cdot K_{\text{IC}}^{-1.6}$ and $D \geq 35$ [μm].

[0035] When such a glass substrate 10 contains Li_2O in an amount of 0.1 to 1 mol% as the glass composition, use of a salt mixture containing KNO_3 and NaNO_3 as molten salt in the chemical strengthening processing is preferable in that a compressive stress layer can be appropriately formed by chemical strengthening.

[0036] (Chemical strengthening processing)

The chemical strengthening processing is processing for immersing the glass substrate in a molten salt having a high temperature and exchanging ions

in the molten salt with ions in the glass. From the viewpoint of ensuring the above-described mechanical strength, the molten salt preferably contains KNO_3 in an amount of 55 to 85 mass%. In this case, the NaNO_3 content percentage is preferably 15 to 45 mass%. It is more preferable that the KNO_3 content percentage in the molten salt is 60 to 80 mass%, and the NaNO_3 content percentage is 20 to 40 mass%. By setting the KNO_3 content percentage to 75 mass% or more, the fracture toughness value K_{IC} increases. It is particularly preferable that the KNO_3 content percentage in the molten salt is 75 to 85 mass%, and the NaNO_3 content percentage is 15 to 25 mass%.

[0037] Processing time during which the glass substrate is immersed in the molten salt in chemical strengthening needs to be adjusted as appropriate in accordance with the temperature of the molten salt, and the processing time is greater than or equal to 2 hours in a range of 400 to 600°C, and is preferably greater than or equal to 4 hours so as to form a deeper compressive stress layer

14. However, if the glass substrate is immersed in the molten salt for a long period of time, the fracture toughness value K_{IC} decreases due to stress relaxation, and the processing time of chemical strengthening increases, and thus the processing time during which the glass substrate is immersed in the molten salt is preferably 20 hours or less. From the above-described viewpoint, the processing time is even more preferably 4 to 16 hours. If the Li_2O content in the glass substrate is 0.1 to 1 mol%, it is difficult to obtain the effect of chemical strengthening, but by performing the chemical strengthening processing at a relatively high temperature for a long period of time in this manner, K_{IC} and the depth D of the compressive stress layer satisfies the above-described ranges, as a result of which a glass substrate having high resistance when damaged can be formed. If the Li_2O content in the glass substrate increases, the Li content in the glass substrate that is exchanged with K in the molten salt in the chemical strengthening processing increases. Moreover, in the present embodiment, as described above, the chemical strengthening processing is performed for a long period of time, and thus K ions

are likely to deeply enter the inner portion of the glass substrate, instead of Li ions. Therefore, there are cases where the thickness of the compressive stress layer that is formed by the chemical strengthening processing increases, but a stress value on the surface of the compressive stress layer easily decreases, and thus K_{IC} cannot be increased. Thus, the Li_2O content in the glass substrate is less than or equal to 1 mol%.

Also, the temperature at which the molten salt is processed in chemical strengthening is preferably greater than or equal to $400^{\circ}C$, and in order to obtain K_{IC} and the depth D of the compressive stress layer in a short period of time, the processing temperature is more preferably set to $450^{\circ}C$ or more. On the other hand, if the processing temperature is excessively high, nitrate used in the chemical strengthening processing decomposes, and thus the processing temperature is preferably set to $570^{\circ}C$ or less. The temperature at which the molten salt is processed is preferably in a range of 400 to $570^{\circ}C$, and is more preferably in a range of 450 to $550^{\circ}C$, for example.

Note that in order to inhibit the chemical strengthening processing from being performed for a period of time that is longer than necessary, the fracture toughness value K_{IC} [$MPa \cdot m^{1/2}$] is preferably less than or equal to 2.5 [$MPa \cdot m^{1/2}$]. From similar reasons, the depth D is preferably less than or equal to 150 μm .

Moreover, when the temperature of a glass substrate is returned to room temperature after the glass substrate is immersed in the molten salt for a predetermined time, in order to obtain the fracture toughness value K_{IC} and the depth D in the above-described ranges, it is preferable that the glass substrate is cooled at a slow cooling speed of $30^{\circ}C/minute$ or less until the temperature of the glass substrate reaches at least $200^{\circ}C$. Also, if the above-described cooling speed is excessively fast, there are cases where minute chipping and cracks easily occur in the end portion of the glass substrate and the mechanical strength decreases, and thus the above-described cooling speed is preferably set to $30^{\circ}C/minute$ or less until the temperature of the glass substrate reaches at

least 200°C.

In order that the glass substrate 10 of the present embodiment satisfies the above-described range of the fracture toughness value K_{IC} and the depth D of the compressive stress layer 14 satisfies the above-described range, it is sufficient that the glass composition and chemical strengthening processing conditions (composition of molten salt, processing time, processing temperature, and cooling speed) are adjusted as appropriate.

[0038] (Glass composition)

An example of the glass composition of the glass substrate 10 of the present embodiment is aluminosilicate glass, for example, which will be described later. That is, the glass substrate 10 contains:

SiO₂ in an amount of 55 to 78 mol%;

Li₂O in an amount of 0.1 to 1 mol%;

Na₂O in an amount of 2 to 15 mol%; and

MgO, CaO, SrO, and BaO in a total amount of 10 to 25 mol%.

A molar ratio of a CaO content with respect to a total content of MgO, CaO, SrO, and BaO ($\text{CaO}/(\text{MgO}+\text{CaO}+\text{SrO}+\text{BaO})$) is less than or equal to 0.20.

By setting the molar ratio $\text{CaO}/(\text{MgO}+\text{CaO}+\text{SrO}+\text{BaO})$ to 0.20 or less, a reduction in the above-described mechanical strength can be suppressed.

Maintenance of the efficiency of ion exchange (molten salt is less likely to deteriorate) and maintenance of the mechanical strength can be realized by setting the molar ratio $\text{CaO}/(\text{MgO}+\text{CaO}+\text{SrO}+\text{BaO})$ to preferably 0.18 or less, more preferably 0.16 or less, and particularly preferably 0.15 or less. In particular, in order to maintain the efficiency of ion exchange (molten salt is less likely to deteriorate), the glass substrate is preferably made of aluminosilicate glass that does not contain Ca. Note that from the viewpoint of a reduction in surface roughness and ease of performing chemical strengthening, the above-described glass is more preferably amorphous aluminosilicate glass.

[0039] (Size of glass substrate)

Although there is no particular limitation on the size of the glass substrate 10, the substrate thickness is 0.3 to 1.5 mm, for example. The glass substrate 10 has a diameter so as to be used in a magnetic disk having a nominal diameter of 2.5 inches, 1 inch, 1.8 inches, 3 inches, 3.5 inches, and the like, for example.

[0040] (Method for manufacturing magnetic-disk glass substrate)

A method for manufacturing such a glass substrate 10 will be described below.

First, processing for molding a glass blank that serves as a raw material for a plate-like magnetic-disk glass substrate having a pair of main surfaces is performed. Next, processing for roughly grinding the glass blank is performed. Thereafter, shape processing and edge surface polishing processing are performed on the glass blank. Then, precision grinding processing is performed on a glass substrate obtained from the glass blank, using fixed abrasive particles. Thereafter, first polishing processing, chemical strengthening processing, and second polishing processing are performed on the glass substrate. Note that although the above-described processes are performed in the above-described flow in the present embodiment, it is not necessary to perform all of the above-described processes and these processes may be omitted as appropriate. Hereinafter, each of the processes will be described.

[0041] (a) Processing for molding glass blank

A press molding method may be used to mold the glass blank, for example. A circular glass blank can be obtained by a press molding method. Furthermore, a glass blank can be manufactured using a known manufacturing method such as a downdraw method, a redraw method, or a fusion method. A disk-shaped glass blank, which is the base of a magnetic-disk glass substrate, can be obtained by appropriately performing shape processing on the plate-like glass blank produced with these known manufacturing methods.

[0042] (b) Rough grinding processing

In the rough grinding processing, specifically, main surfaces on both sides of the glass blank are ground while the glass blank is held in a holding hole provided in a holding member (carrier) mounted on a known double-side grinding apparatus. Loose abrasive particles are used as an abrasive, for example. In the rough grinding processing, grinding is performed such that the glass blank is brought approximately closer to a target substrate thickness and a target flatness of the main surfaces. Note that the rough grinding processing is performed in accordance with the dimensional accuracy or the surface roughness of the molded glass blank, and may be omitted in some cases.

10 [0043] (c) Shape processing

Next, shape processing is performed. In the shape processing, after the processing for molding the glass blank, a circular hole is formed using a known processing method to obtain a disk-shaped glass substrate having the circular hole. Thereafter, chamfering is performed on edge surfaces of the glass substrate. Accordingly, side wall surfaces orthogonal to the main surfaces and inclined surfaces (interposed surfaces) that connect the side wall surfaces and the main surfaces are formed on the edge surfaces of the glass substrate.

[0044] (d) Edge surface polishing processing

20 Next, processing for polishing edge surfaces of the glass substrate is performed. The edge surface polishing processing is processing for performing polishing by supplying a polishing liquid containing loose abrasive particles between a polishing brush and the edge surfaces of the glass substrate and moving the polishing brush and the edge surfaces of the glass substrate relative to each other. In edge surface polishing, an inner side edge surface and an outer side edge surface of the glass substrate are polishing targets, and the inner side edge surface and the outer side edge surface are formed into mirror surfaces.

[0045] (e) Precision grinding processing

30 Next, precision grinding processing is performed on the main surfaces

on both sides of the glass substrate. Specifically, grinding is performed on the main surfaces of the glass substrate using a known double-side grinding apparatus. For example, fixed abrasive particles are provided on surface plates and the glass substrate is ground. Specifically, the main surfaces on
5 both sides of the glass substrate are ground while the glass substrate is held in a holding hole provided in a carrier, which is a holding member of the double-side grinding apparatus.

Although the main surfaces of the glass substrate are ground by bringing grinding surfaces containing the fixed abrasive particles and the main
10 surfaces of the glass substrate into contact with each other in the grinding processing of the present embodiment, grinding using loose abrasive particles may be performed.

[0046] (f) First polishing processing

Next, first polishing processing is performed on the main surfaces on
15 both sides of the glass substrate. Specifically, the main surfaces on both sides of the glass substrate 10 are polished while an outer circumferential side edge surface of the glass substrate is held in the holding hole provided in the carrier of the polishing apparatus. In the first polishing processing, loose abrasive particles and polishing pads attached to the surface plates are used. First
20 polishing adjusts the thickness of the glass substrate 10 and removes cracks and warping remaining on the main surfaces in the case where grinding is performed with fixed abrasive particles, for example. In first polishing, it is possible to reduce the surface roughness of the main surfaces, that is, the arithmetic average roughness Ra, for example while preventing the shape of
25 the end portions of the main surfaces from excessively recessing or protruding.

Although there is no particular limitation on the loose abrasive particles used in first polishing, cerium oxide abrasive particles, zirconia abrasive particles, or the like are used, for example.

Although there is no particular limitation on the type of polishing pad,
30 for example, a hard urethane resin foam polisher is used.

[0047] (g) Chemical strengthening processing

Next, the glass substrate is subjected to the above-described chemical strengthening processing using molten salt. As the molten salt, molten salt obtained by heating a mixture of potassium nitrate and sodium nitrate, for example can be used. Also, potassium nitrate or sodium nitrate may be used alone as well. Moreover, by immersing the glass substrate in the molten salt, Li ions and Na ions in the glass composition that are present in a surface layer of the glass substrate 10 are respectively substituted with Na ions and K ions whose ion radius in a chemical strengthening liquid are relatively large, which forms compressive stress layers on the surfaces of the glass substrate 10, and the glass substrate 10 is strengthened.

Although the time at which the chemical strengthening processing is performed is determined as appropriate, the polishing processing is particularly preferably performed after the chemical strengthening processing, because the surface can be smoothed and foreign matter attached to the surface of the glass substrate can be removed by the chemical strengthening processing.

[0048] (h) Second polishing (mirror-polishing) processing

Next, second polishing is performed on the glass substrate that has undergone the chemical strengthening processing. Second polishing is for performing mirror-polishing on the main surfaces. A known double-side polishing apparatus is also used in second polishing. Doing so makes it possible to reduce the roughness of the main surfaces while preventing the shape of end portions of the main surfaces of the glass substrate 10 from excessively recessing or protruding. The second polishing processing differs from the first polishing processing in terms of the loose abrasive particles, and the particle size of the loose abrasive particles used in the second polishing processing is smaller than the particle size of those used in the first polishing processing. Furthermore, the hardness of a resin polisher of a polishing pad used in the second polishing processing is preferably less than the hardness of

the resin polisher of the polishing pad used in the first polishing processing.

That is, the polishing pad 10 is easily depressed by pressure at the time of second polishing.

[0049] Minute particles of colloidal silica or the like, for example, are used as
5 the loose abrasive particles used in the second polishing processing. In order
to not eliminate the effect of the compressive stress layer formed at the time of
the chemical strengthening processing, the machining allowance of the second
polishing processing is preferably less than or equal to 2 μm in terms of a
substrate thickness. A magnetic-disk glass substrate can be obtained by
10 cleaning the polished glass substrate. The glass substrate 10 on which the
second polishing processing is performed in this manner serves as a
magnetic-disk glass substrate.

[0050] [Working Examples]

In order to examine the effect of the present embodiment, the glass
15 substrates were produced by preparing glass raw material such that glass
substrates had the above-described glass composition, and chemical
strengthening was performed on the glass substrates under various conditions.
The glass substrate contained, as a basic glass composition, SiO_2 in an amount
of 65.5 mol%, Al_2O_3 in an amount of 5 mol%, Li_2O in an amount of 1 mol%,
20 Na_2O in an amount of 9 mol%, MgO in an amount of 16 mol%, and ZrO_2 in an
amount of 3.5 mol%. At that time, three different Li_2O content percentages
were used while the content of Li_2O and Na_2O was kept constant, that is, 10
mol%. With respect to the glass substrates on which chemical strengthening
had been performed, the above-described fracture toughness value K_{IC} was
25 measured and the depth D of a compressive stress layer was measured using a
known Babinet compensator method. Also, the mechanical strength (flexural
strength $[\text{N}]$) of the glass substrates on which the above-described damage
addition processing had been performed was checked with the above-described
method. In the mechanical strength (flexural strength) testing, 100 glass
30 substrates that had the same glass composition and were processed under the

same chemical strengthening conditions were checked as test subjects, and the case where the flexural strength was greater than or equal to 60 N was judged as acceptable and the pass rates thereof were obtained. The condition that the pass rate of the glass substrate is greater than or equal to 95% was set as the
5 condition suitable for a magnetic disk.

Table 1 below shows the Li_2O content percentage in glass, molten salt composition (content ratio of KNO_3 and NaNO_3), molten salt temperature, the details of conditions obtained by changing chemical strengthening processing time in various ways, the fracture toughness value K_{IC} of a glass substrate, the
10 depth D of a compressive stress layer, a flexural strength (average value), and a pass rate.

[0051] [Table 1]

	Li ₂ O content percentage [mol%]	Molten salt composition	Molten salt temperature [°C]	Chemical strengthening processing time [hours]	K _{1c} [MPa·m ^{1/2}]	Depth D of compressive stress layer [μm]	Flexural strength [Kgf]	Pass rate [%]
1	0.1	6:4	400	4	0.7	11	9.7	80
2				8	0.8	10	9.6	90
3				16	1.2	49	13.9	96
4			450	4	1.0	17	13.0	88
5				8	1.1	56	10.5	95
6				16	1.4	45	15.9	98
7		8:2	400	4	0.9	16	12.1	72
8				8	0.9	26	10.5	88
9				16	1.4	41	13.0	95
10			450	4	1.3	10	15.0	73
11				8	1.4	25	14.0	85
12				16	1.5	34	16.9	95
13		10:0		4	2.3	19	17.3	70
14	0.6	2:8	400	4	0.7	41	13.2	88
15				8	0.8	53	14.3	90
16				16	1.1	40	14.9	93
17			450	4	0.7	92	15.6	93
18				8	1.1	102	18.0	96
19				16	1.4	101	19.1	98
20		6:4	400	4	1.3	20	15.0	91
21				8	1.4	37	15.0	97
22				16	1.3	55	15.0	98
23			450	4	1.3	76	15.8	98
24				8	1.6	80	17.8	99
25				16	1.6	92	17.8	100
26		8:2	400	4	0.8	10	11.6	81
27				8	1.1	29	13.9	89
28				16	1.1	78	12.1	95
29			450	4	1.6	19	17.8	93
30				8	1.8	27	17.8	96
31				16	1.9	56	15.3	98
32	1.0	4:6	450	4	0.9	112	12.0	94
33		6:4	400	4	1.5	16	15.8	88
34				8	1.4	36	17.9	97
35				16	1.6	40	17.8	98
36			450	4	1.5	92	18.5	99
37				8	1.7	102	18.8	100
38				16	1.8	101	17.4	99
39		8:2	400	4	1.6	10	18.5	83
40				8	2.1	15	21.9	93
41				16	1.9	26	19.1	96
42			450	4	2.0	30	15.8	95
43				8	2.2	65	18.8	98
44				16	2.2	75	21.1	99

[0052] The results of Table 1 above are summarized as a region of conditions suitable for a magnetic disk, where conditions under which the pass rate is 95% or more are conditions suitable for a magnetic disk, the region being shown in FIG. 5 as a hatched region. A circle mark in FIG. 5 means that the pass rate is greater than or equal to 98%, a triangle mark means that the pass rate is greater than or equal to 95% and is less than 98%, and a cross mark means that

the pass rate is less than 95%. Therefore, the circle mark and the triangle mark mean being suitable for a magnetic disk. According to this, it was found that in order that a glass substrate containing Li_2O in an amount of 0.1 to 1 mol% as the glass composition reliably has a mechanical strength (flexural strength) suitable for a magnetic disk, the fracture toughness value K_{IC} needs to be greater than or equal to 1 [$\text{MPa} \cdot \text{m}^{1/2}$], the depth D of the compressive stress layer 14 needs to satisfy $D \geq 57 \cdot K_{\text{IC}}^{-1.6}$ and $D \geq 20$ [μm]. A more preferable range is a range in which the fracture toughness value K_{IC} [$\text{MPa} \cdot \text{m}^{1/2}$] is greater than or equal to 1.2 [$\text{MPa} \cdot \text{m}^{1/2}$], and the depth D [μm] of the compressive stress layer 14 satisfies $D \geq 70 \cdot K_{\text{IC}}^{-1.6}$ and $D \geq 35$ [μm].

Note that using the above-described basic composition excluding Li_2O and Na_2O , in the case of an example in which the Li_2O content is 0 mol% and the Na_2O content is 10 mol% and in the case of an example in which the Li_2O content is 0.05 mol% and the Na_2O content is 9.95 mol%, the depth D was less than or equal to 5 μm and the pass rates were all less than 95%. It is inferred that the reason for this is that ion exchange was not favorably performed in the chemical strengthening processing due to the Li_2O content being too small.

Also, using the above-described basic composition excluding Li_2O and Na_2O , in the case where the Li_2O content was 1.5 mol% and the Na_2O content was 8.5 mol%, the glass transition point temperature T_g was less than 650°C. [0053] As described above, the glass substrate 10 of the present embodiment is summarized as follows.

(1) A glass substrate made of glass containing Li_2O in an amount of 0.1 to 1 mol%, the glass substrate in which a fracture toughness value K_{IC} [$\text{MPa} \cdot \text{m}^{1/2}$] is greater than or equal to 1 [$\text{MPa} \cdot \text{m}^{1/2}$], and compressive stress layers are provided on surfaces of the glass substrate through chemical strengthening, a depth D [μm] of the compressive stress layer satisfying $D \geq 57 \cdot K_{\text{IC}}^{-1.6}$, and $D \geq 20$ [μm] having a glass transition point temperature higher than that of a conventional glass substrate, and reliably having a mechanical strength (flexural strength) suitable for a magnetic disk. Also, it was found that in

order that the fracture toughness value K_{IC} and the depth D of the compressive stress layer satisfy the above-described ranges and the glass substrate reliably has a mechanical strength (flexural strength), the glass substrate needs to contain Li_2O in an amount of 0.1 to 1 mol%.

5 (2) The glass substrate can be preferably used as an energy-assisted magnetic-disk glass substrate by setting the glass transition point temperature to 650°C or more.

(3) A glass substrate made of glass containing SiO_2 in an amount of 55 to 78 mol%, Li_2O in an amount of 0.1 to 1 mol%, Na_2O in an amount of 2 to 15 mol%,
 10 and MgO , CaO , SrO , and BaO in a total amount of 10 to 25 mol%, the glass in which a molar ratio of the CaO content with respect to the total content of MgO , CaO , SrO and BaO ($CaO/(MgO+CaO+SrO+BaO)$) is less than or equal to 0.20, and a glass substrate made of aluminosilicate glass that does not contain Ca can maintain the efficiency of ion exchange in chemical strengthening similarly
 15 to the conventional glass substrate, and can maintain a mechanical strength similar to that of the conventional glass substrate.

(4) In chemical strengthening, when the glass substrate is immersed in a liquid molten salt mixture of KNO_3 and $NaNO_3$, the molten salt mixture contains KNO_3 in an amount of 55 to 85 mass%, which realizes the depth D of the
 20 above-described compressive stress layer.

[0054] Although a magnetic-disk glass substrate, a method for manufacturing a magnetic-disk glass substrate, and a magnetic disk of the present invention have been described in detail above, the present invention is not limited to the above-described embodiment or working examples, and it will be appreciated
 25 that various improvements and modifications can be made without departing from the gist of the present invention.

[Descriptions of Reference Numerals]

[0055]	10	Magnetic-disk glass substrate
	12	Surface
30	14	Compressive stress layer

- 16 Tensile stress layer
- 18 Steel ball

CLAIMS

1. A magnetic-disk glass substrate comprising
as a glass composition, Li_2O in an amount of 0.1 to 1 mol%, the glass
5 substrate being made of amorphous aluminosilicate glass, wherein
a fracture toughness value K_{IC} [$\text{MPa} \cdot \text{m}^{1/2}$] is greater than or equal to 1
[$\text{MPa} \cdot \text{m}^{1/2}$], and
a compressive stress layer is provided on a surface of the glass substrate
by chemical strengthening, a depth D [μm] of the compressive stress layer
10 satisfying $D \geq 57 \cdot K_{IC}^{-1.6}$, and $D \geq 20$ [μm].
2. The magnetic-disk glass substrate according to claim 1, wherein
a glass transition point temperature T_g is greater than or equal to
650°C.
- 15 3. The magnetic-disk glass substrate according to claim 1 or 2, comprising:
as the glass composition,
 SiO_2 in an amount of 55 to 78 mol%;
 Li_2O in an amount of 0.1 to 1 mol%;
20 Na_2O in an amount of 2 to 15 mol%; and
 MgO , CaO , SrO , and BaO in a total amount of 10 to 25 mol%, wherein
a molar ratio of a CaO content with respect to a total content of MgO ,
 CaO , SrO , and BaO ($\text{CaO}/(\text{MgO} + \text{CaO} + \text{SrO} + \text{BaO})$) is less than or equal to 0.20.
- 25 4. The magnetic-disk glass substrate according to any one of claims 1 to 3,
comprising
as the glass composition, aluminosilicate glass that does not contain Ca .
5. A magnetic disk comprising the magnetic-disk glass substrate according
30 to any one of claims 1 to 4, and a magnetic layer formed on the surface of the

glass substrate.

6. A method for manufacturing a magnetic-disk glass substrate, comprising:

5 processing for producing a disk-shaped glass substrate that contains Li_2O in an amount of 0.1 to 1 mol%, the glass substrate being made of amorphous aluminosilicate glass; and

processing for performing chemical strengthening on the glass substrate such that a fracture toughness value K_{IC} [$\text{MPa} \cdot \text{m}^{1/2}$] is greater than
 10 or equal to 1 [$\text{MPa} \cdot \text{m}^{1/2}$], and a depth D [μm] of a compressive stress layer to be provided on a surface of the glass substrate by the chemical strengthening satisfies $D \geq 57 \cdot K_{\text{IC}}^{-1.6}$ and $D \geq 20$ [μm].

7. The method for manufacturing a magnetic-disk glass substrate
 15 according to claim 6, wherein

the chemical strengthening processing is processing for immersing the glass substrate in a liquid molten salt mixture containing KNO_3 and NaNO_3 , and the molten salt mixture contains KNO_3 in an amount of 55 to 85 mass%.

20 8. The method for manufacturing a magnetic-disk glass substrate according to claim 6 or 7, wherein

the glass substrate that has undergone the chemical processing contains:

as a glass composition,

25 SiO_2 in an amount of 55 to 78 mol%;

Li_2O in an amount of 0.1 to 1 mol%;

Na_2O in an amount of 2 to 15 mol%; and

MgO , CaO , SrO , and BaO in a total amount of 10 to 25 mol%, and

a molar ratio of a CaO content with respect to a total content of MgO ,
 30 CaO , SrO , and BaO ($\text{CaO}/(\text{MgO} + \text{CaO} + \text{SrO} + \text{BaO})$) is less than or equal to 0.20.

9. The method for manufacturing a magnetic-disk glass substrate according to any one of claims 6 to 8, wherein

the glass substrate comprises aluminosilicate glass that does not
5 contain Ca.