DESCRIPTION

[Title of Invention]

GLASS SUBSTRATE

[Technical Field]

[0001] The present invention relates to a glass substrate.

[Background Art]

[0002] In recent years, the recording density of a medium for a hard disk drive needs to be about 600 Gbit/inch^2. In order to achieve such a high recording density, it is necessary to further suppress fluttering of a glass substrate used as a substrate for a medium for a hard disk drive from the viewpoint of accuracy in positioning of a head, and thus such a glass substrate needs to have a high Young's modulus (high elasticity).

[0003] Moreover, from the viewpoint of increasing recording density, the glass substrate needs to support a heat-assisted method, and the formation of a recording layer (magnetic layer) that supports the heat-assisted method needs film formation processing at high temperature, and thus a glass substrate on which the recording layer is formed needs high heat resistance. Therefore, JP 2005-314159A (Patent Literature 1) proposes a glass substrate having heat resistance.

[Citation List]

[Patent Literature]

[0004] [PLT1]: JP 2005-314159A

[Summary of Invention]

[Technical Problem]

[0005] The proposed glass substrate had heat resistance to some extent, but did not have a high Young's modulus. Thus, fluttering could not be sufficiently suppressed. On the other hand, from the viewpoint of heat generation of a hard disk drive, a glass substrate having a low specific gravity, which does not

put a load on a motor, is preferable, but it has been very difficult to obtain a glass substrate that has a low specific gravity, high elasticity, and high heat resistance.

[0006] The present invention has been made in view of such circumstances, and an object thereof is to provide a glass substrate having excellent heat resistance, a high Young's modulus, and a low density.

[Solution to Problem]

[0007] A glass substrate of the present invention has a glass composition in which

in mol%, the following content ranges:

SiO_2: 58 to 67%;

Al_2O_3: 6.5 to 13%;

B_2O_3: 0 to 3%;

Li_2O: 2.3 to 6.5%;

Na_2O: 0.2 to 2.5%;

K_2O: 0 to 2%;

MgO: 14 to 23%;

CaO: 0.6 to 4.6%;

SrO: 0 to 3%;

BaO: 0 to 3%;

ZnO: 0 to 3%;

ZrO_2: 0 to 3%;

CeO_2: 0 to 2%;

SnO_2: 0 to 2%;

TiO_2: 0 to 4%; and

Nb_2O_5: 0 to 3% are satisfied, and

in mol%, the following condition:

$SiO_2+Al_2O_3+B_2O_3$: 67 to 76% is satisfied, and

the following ratios (indicated in "mole fractions"):

$0.6 \leq Li_2O/(LiO_2+Na_2O+K_2O) \leq 0.96$; and

$0.78 \leq MgO/(MgO+CaO+SrO+BaO+ZnO) \leq 0.98$ are satisfied.

[0008] Here, the glass substrate preferably has a Young's modulus of 90 GPa or more and 101 GPa or less, preferably has a density of 2.49 g/cm^3 or more and 2.61 g/cm^3 or less, and preferably has a glass transition temperature of 635°C or more and 725°C or less, and a thickness t (unit: mm) of the glass substrate and an outer diameter d (unit: mm) of the glass substrate are preferably in the following relationship: $t/d \leq 0.011$.

[0009] Also, the glass substrate is preferably a glass substrate for a magnetic recording medium, and a surface of the glass substrate is preferably subjected to chemical strengthening processing.

[ADVANTAGEOUS EFFECTS OF INVENTION]

[0010] Since the glass substrate of the present invention has the above-described configuration, the glass substrate has excellent effects of having excellent heat resistance, exhibiting a high Young's modulus, and having a low density.

[Description of Embodiments]

[0011] Hereinafter, an embodiment according to the present invention will be further described in detail.

<Glass substrate>

A glass substrate of the present embodiment can be usefully used as a substrate for an information recording medium in various information recording apparatuses, and in particular, as a glass substrate for a magnetic recording medium in a magnetic recording apparatus such as a hard disk drive apparatus, and has a glass composition in which

in mol%, the following content ranges:

SiO_2: 58 to 67%;

Al_2O_3: 6.5 to 13%;

B_2O_3: 0 to 3%;

Li_2O: 2.3 to 6.5%;

Na_2O: 0.2 to 2.5%;

K_2O: 0 to 2%;

MgO: 14 to 23%;

CaO: 0.6 to 4.6%;

SrO: 0 to 3%;

BaO: 0 to 3%;

ZnO: 0 to 3%;

ZrO_2: 0 to 3%;

CeO_2: 0 to 2%;

SnO_2: 0 to 2%;

TiO_2: 0 to 4%; and

Nb_2O_5: 0 to 3% are satisfied, and

in mol%, the following condition:

$SiO_2+Al_2O_3+B_2O_3$: 67 to 76% is satisfied, and

the following ratios:

$0.6 \leq Li_2O/(Li_2O+Na_2O+K_2O) \leq 0.96$; and

$0.78 \leq MgO/(MgO+CaO+SrO+BaO+ZnO) \leq 0.98$ are satisfied.

[0012] Here, in the present embodiment, with regard to the glass composition, "%" indicates "mol%" unless otherwise stated in particular. Also, addition notation of chemical formulae such as "$SiO_2+Al_2O_3+B_2O_3$" indicates the total amount of the components expressed by such chemical formulae. Therefore, "$SiO_2+Al_2O_3+B_2O_3$" indicates the total amount of SiO_2, Al_2O_3, and B_2O_3, and the total amount thereof in the above-described case is 67 to 76 mol% with respect to the entire glass composition.

[0013] Also, the notation "$Li_2O/(Li_2O+Na_2O+K_2O)$" indicates the proportion (ratio) of Li_2O with respect to the total amount of Li_2O, Na_2O, and K_2O, and the above-described case indicates that the ratio thereof is 0.6 or more and is 0.96 or less. Similarly, the notation "MgO/(MgO+CaO+SrO+BaO+ZnO)" indicates the proportion (ratio) of MgO with respect to the total amount of MgO, CaO, SrO, BaO, and ZnO, and the above-described case indicates that the ratio thereof is 0.78 or more and 0.98 or less.

[0014] Since the glass substrate of the present embodiment has a glass composition such as that described above, the glass substrate has excellent effects of ensuring sufficient elasticity (high Young's modulus), thereby improving fluttering characteristics, and achieving a low specific gravity (low density) while ensuring a high Young's modulus and heat resistance. Such excellent effects are achieved by the properties of components that constitute the glass composition and will be described later being exhibited synergistically.

[0015] Note that the glass substrate of the present embodiment preferably has a disk shape (a hole for attaching the glass substrate to an information recording apparatus may be created in a central portion), and accordingly is suitable for a glass substrate for an information recording medium (magnetic recording medium) to be installed in an information recording apparatus such as a hard disk drive apparatus, for example. In the case of having a disk shape, there is no particular limitation on the size, and for example, a small disk having an outer diameter of 3.5 inches, 2.5 inches, 1.8 inches, or smaller than 1.8 inches is possible, and a thin disk having a thickness of 1 mm, 0.8 mm, 0.7 mm, 0.635 mm, 0.5 mm, or thinner than 0.5 mm is also possible.

[0016] In particular, in the glass substrate of the present embodiment, a thickness t (unit: mm) of the glass substrate and an outer diameter d (unit: mm) of the glass substrate are preferably in the following relationship: $t/d \leq 0.011$. Accordingly, the substrate weight per unit storage capacity in a hard disk drive can be reduced, which is preferable from the viewpoint of power consumption. Note that from the viewpoint of fluttering characteristics, the lower limit of t/d is preferably greater than or equal to 0.006.

[0017] Note that in the present embodiment, the thickness of the glass substrate is a length in a direction perpendicular to a recording surface (surface having the largest area), and is an average value of lengths in the plane direction of the recording surface.

[0018] <Glass composition>

Constituent components included in a glass composition of the glass substrate of the present embodiment will be described below.

[0019] First, SiO_2 included in the glass composition of the present embodiment is an important component that forms a network structure of glass. If the content of SiO_2 is less than 58%, it becomes difficult to form glass, and there is a risk that chemical resistance will deteriorate. In contrast, if the content of SiO_2 exceeds 67%, meltability deteriorates. Therefore, the content of SiO_2 needs to be in a content range of 58 to 67%. A more preferable content range of SiO_2 is 59 to 65%. Note that it is assumed that in the case where mol% is indicated using a range like "58 to 67%" in the present embodiment, this range includes the numerical values of the upper limit and the lower limit, and is "58% or more and 67% or less" in the above-described case.

[0020] Al_2O_3 is an important component that forms the network structure together with SiO_2, and has a function of not only increasing heat resistance but also improving ion exchange performance. If the content of Al_2O_3 is less than 6.5%, there is a risk that chemical resistance or ion exchange performance will decrease. In contrast, if the content of Al_2O_3 exceeds 13%, ion exchange performance decreases, and meltability deteriorates. Therefore, the content of Al_2O_3 needs to be in a content range of 6.5 to 13%. In this content range, the content of Al_2O_3 is preferably in a range of 6.6 to 9.6%.

[0021] B_2O_3 is a component that forms the network structure together with SiO_2, and has a function of reducing a melting temperature, and therefore B_2O_3 is included as needed. If the content of B_2O_3 exceeds 3%, a glass transition temperature (Tg) that serves as an index of heat resistance decreases. Therefore, the content of B_2O_3 needs to be in a content range of 0 to 3%. A more preferable content range of B_2O_3 is 0 to 2%. Note that in the above description, 0% in 0 to 3% B_2O_3 content means that an aspect in which B_2O_3 is not included may be encompassed. Note that the notation "0%" in the glass composition of the present embodiment is similar to this, and means that an aspect in which the component is not included may be encompassed.

[0022] Li_2O is a component required for increasing chemical resistance and meltability. If the content of Li_2O is less than 2.3%, the effect of suppressing Li elution and the effect of increasing meltability cannot be sufficiently obtained. In contrast, if the content of Li_2O exceeds 6.5%, a glass transition temperature (Tg) decreases and Li elution worsens. Therefore, the content of Li_2O needs to be in a content range of 2.3 to 6.5%. In this content range, the content of Li_2O is preferably in a content range of 4.5 to 6%.

[0023] Na_2O plays a role of increasing meltability. If the content of Na_2O is less than 0.2%, the effect of suppressing Na elution and the effect of increasing meltability cannot be sufficiently obtained. In contrast, if the content of Na_2O exceeds 2.5%, chemical resistance decreases. Therefore, the content of Na_2O needs to be in a content range of 0.2 to 2.5%. In this content range, the content of Na_2O is preferably in a content range of 0.5 to 2.5%.

[0024] K_2O has an effect of improving meltability, and thus may be included as needed. If the content of K_2O exceeds 2%, a glass transition temperature (Tg) decreases and chemical resistance also deteriorates. Therefore, the content of K_2O is set to be in a content range of 0 to 2%. A more preferable content range of K_2O is 0 to 1%.

[0025] MgO has an effect of increasing heat resistance and improving meltability. Also, MgO has an effect of increasing elasticity (Young's modulus) while keeping the density low. If the content of MgO is less than 14%, the effect of increasing heat resistance and the effect of improving meltability cannot be obtained, and elasticity is low and fluttering characteristics deteriorate. In contrast, if the content of MgO exceeds 23%, the glass structure becomes unstable, and devitrification resistance deteriorates, as a result of which it becomes difficult to mold glass. Therefore, the content of MgO is set to be in a content range of 14 to 23%. The content range of MgO is one feature point of the present embodiment. A more preferable content range of MgO is 16 to 21%.

[0026] CaO has an effect of improving meltability and an effect of maintaining

the glass transition temperature (Tg). If the content of CaO is less than 0.6%, the effect of improving meltability and the effect of maintaining the glass transition temperature (Tg) cannot be obtained sufficiently, and in contrast, if the content of CaO exceeds 4.6%, the glass structure becomes unstable, and chemical resistance deteriorates. Therefore, the content of CaO is set to be in a content range of 0.6 to 4.6%. A more preferable content range of CaO is 0.6 to 2.6%.

[0027] SrO has an effect of improving meltability and an effect of maintaining the glass transition temperature (Tg), and thus is included as needed. If the content of SrO exceeds 3%, devitrification resistance deteriorates and it becomes difficult to mold glass. Therefore, the content of SrO is set to be in a content range of 0 to 3%. A more preferable content range of SrO is 0 to 2%.

[0028] BaO has an effect of improving meltability and an effect of maintaining the glass transition temperature (Tg), and thus is included as needed. If the content of BaO exceeds 3%, devitrification resistance deteriorates and it becomes difficult to mold glass. Therefore, the content of BaO is set to be in a content range of 0 to 3%. A more preferable content range of BaO is 0 to 2%.

[0029] ZnO has an effect of increasing chemical resistance and improving meltability, and thus is included as needed. If the content of ZnO exceeds 3%, the glass structure becomes unstable, and devitrification resistance deteriorates. Therefore, the content of ZnO is set to be in a content range of 0 to 3%. A more preferable content range of ZnO is 0 to 2%.

[0030] ZrO_2 has an effect of increasing heat resistance of glass, and thus may be included as needed. However, if the content of ZrO_2 exceeds 3%, devitrification resistance deteriorates and it becomes difficult to form glass. Therefore, the content of ZrO_2 is set to be in a content range of 0 to 3%. In this content range, the content of ZrO_2 is preferably in a content range of 0 to 2%.

[0031] CeO_2 and SnO_2 serve as fining agents, and thus may be included as needed. If the content of CeO_2 and the content of SnO_2 respectively exceed 2%, devitrification resistance deteriorates and it becomes difficult to form glass.

Therefore, the content of CeO_2 and the content of SnO_2 are respectively set to be in a content range of 0 to 2%. More preferable content ranges of CeO_2 and SnO_2 are respectively 0 to 1%.

[0032] TiO_2 has an effect of reducing viscosity at high temperature and increasing chemical resistance, and thus is included as needed. If the content of TiO_2 exceeds 4%, the glass structure becomes unstable, and devitrification resistance deteriorates, as a result of which it becomes difficult to mold glass. Therefore, the content of TiO_2 is set to be in a content range of 0 to 4%. A more preferable content range of TiO_2 is 0 to 3%.

[0033] Nb_2O_5 has an effect of increasing meltability and chemical resistance, and thus may be included as needed. If the content of Nb_2O_5 exceeds 3%, the liquid phase temperature increases and devitrification resistance deteriorates. Also, a specific gravity increases. Therefore, the content of Nb_2O_5 is set to be in a range of 0 to 3%. A more preferable content range of Nb_2O_5 is 0 to 1%.

[0034] The glass composition of the present embodiment may include components other than the above-described components. For example, there are no particular limitations on components that serve as fining agents such as Sb_2O_3, and such components may be included in a content range of 0 to 2%.

[0035] On the other hand, with regard to the glass composition of the present embodiment, it is important to set the total amount of SiO_2, Al_2O_3, and B_2O_3 ($SiO_2+Al_2O_3+B_2O_3$) to be 67 to 76%. That is, the total amount of SiO_2, Al_2O_3, and B_2O_3 with respect to the entire glass composition needs to be 67 to 76 mol%. These are important components that form the network structure of glass as described above, and if the total amount thereof is less than 67%, it becomes difficult to form glass. In contrast, if the total amount thereof exceeds 76%, the viscosity is so high that meltability deteriorates. In this range, the total amount thereof is preferably in a range of 68 to 75%.

[0036] Moreover, in the glass composition of the present embodiment, the ratio of Li_2O with respect to the total amount of Li_2O, Na_2O, and K_2O needs to be 0.6 to 0.96, or that is, $0.6 \leq Li_2O/(Li_2O+Na_2O+K_2O) \leq 0.96$ needs to be satisfied. If

the ratio thereof is less than 0.6, the density (specific gravity) increases, and if the ratio thereof exceeds 0.96, the Li elution amount increases. More preferably, $0.8 \leq Li_2O/(Li_2O+Na_2O+K_2O) \leq 0.96$ is satisfied.

[0037] Also, in the glass composition of the present embodiment, the ratio of MgO with respect to the total amount of MgO, CaO, SrO, BaO, and ZnO needs to be 0.78 to 0.98, or that is, $0.78 \leq MgO/(MgO+CaO+SrO+BaO+ZnO) \leq 0.98$ needs to be satisfied. If the ratio of MgO is less than 0.78, the density (specific gravity) increases, and if the ratio thereof exceeds 0.98, the glass structure becomes unstable, and devitrification resistance deteriorates, as a result of which it becomes difficult to mold glass. More preferably, $0.86 \leq MgO/(MgO+CaO+SrO+BaO+ZnO) \leq 0.98$ is satisfied.

[0038] <Characteristics>

The glass substrate of the present embodiment preferably has characteristics such as those described below.

[0039] <Young's modulus and density>

The glass substrate of the present embodiment has a glass composition such as that described above, and thus can have a Young's modulus of 90 GPa or more and 101 GPa or less, and have a density of 2.49 g/cm^3 or more and 2.61 g/cm^3 or less. If the Young's modulus is less than 90 GPa, there are cases where fluttering characteristics deteriorate. Also, if the Young's modulus exceeds 101 GPa, there are cases where processability is problematic. Also, if the density is less than 2.49 g/cm^3, there are cases where rigidity is likely to decrease. Moreover, if the density exceeds 2.61 g/cm^3, there are cases where the load on the motor increases and heat is excessively generated in a hard disk drive.

[0040] A more preferable Young's modulus is 95 GPa or more and 98 GPa or less, and a more preferable density is 2.52 g/cm^3 or more and 2.57 g/cm^3 or less.

[0041] <Glass transition temperature>

The glass substrate of the present embodiment preferably has a glass transition temperature (Tg) of 635°C or more and 725°C or less. If the Tg is

less than 635°C, in the step of manufacturing a medium (information recording medium) that is to use a heat-assisted method, there are cases where deformation occurs due to heating in a film formation step. Also, if the Tg exceeds 725°C, a good shape of a blank cannot be obtained in the step of molding glass blanks, which adversely affects the final shape of the glass substrate and dynamic characteristics of the medium. A more preferable glass transition temperature (Tg) is 650°C or more and 710°C or less.

[0042] <Chemical strengthening processing>

Surfaces of the glass substrate of the present embodiment are preferably subjected to chemical strengthening processing. Usually, such chemical strengthening processing can be performed by immersing a glass substrate in a solution containing alkali in the step of manufacturing a glass substrate. More specifically, the chemical strengthening processing is ion exchange processing in which alkaline metal ions such as lithium ions and sodium ions included in a glass substrate are substituted with alkali metal ions such as potassium ions having an ion radius larger than that of lithium ions and sodium ions.

[0043] Chemical strengthening processing is preferable because if surfaces of a glass substrate are subjected to chemical strengthening processing in this manner, compressive stress occurs due to warping caused by a difference in ion radius mainly in a region where ions are exchanged, and the hardness of the surfaces of the glass substrate increases in this region.

[0044] <Manufacturing method>

There is no particular limitation on the method for manufacturing a glass substrate of the present embodiment, and a conventionally known manufacturing method can be used. For example, as raw materials of components constituting a glass substrate, corresponding oxides, carbonates, nitrates, hydroxides, and the like are used, and these components are weighed into a predetermined ratio, and sufficiently mixed in powder form to prepare a blended raw material.

[0045] If this blended raw material is introduced into a platinum crucible or the like in an electric furnace that is heated to 1300 to 1550°C, for example, and after the blended raw material is melted and fined, the material is homogenized by stirring, cast into a pre-heated mold, and annealed to prepare a glass block. Next, after the resulting material is held at a temperature near a glass transition temperature for 1 to 3 hours, the resulting material is annealed to remove warping.

[0046] Subsequently, the obtained glass block is sliced into a disc shape and is cut using a core drill with the inner circumference and the outer circumference concentric with each other. Alternatively, molten glass is press-molded into a disk shape. Then, after both surfaces of the disk-shaped glass substrate obtained in this manner are subjected to rough polishing and fine polishing, the disk-shaped glass substrate is cleaned with at least one of water, an acidic solution, and an alkaline solution to prepare a final glass substrate.

[0047] Note that chemical strengthening may be performed on the glass substrate of the present embodiment by immersing the glass substrate in a mixed solution of potassium nitrate (50 wt%) and sodium nitrate (50 wt%) after rough polishing and polishing are performed on both surfaces of the glass substrates in the above-described manufacturing step. Also, thereafter, a portion of a chemical strengthened layer may be removed as needed.

[0048] A magnetic layer (magnetic film) serving as a recording layer is then formed on the glass substrate of the present embodiment manufactured in this manner to prepare an information recording medium (magnetic recording medium). This information recording medium can be used while incorporated in an information recording apparatus such as a hard disk drive apparatus.

Working Examples

[0049] Hereinafter, although the present invention will be described in detail using working examples, the present invention is not limited to these.

[0050] <Working Examples 1 to 30 and Comparative Examples 1 to 8>

Predetermined amounts of powder raw materials were weighed and

introduced into platinum crucibles so as to obtain the glass compositions (constituent components and ratios) shown in Tables 1 and 4, and after mixing, the resulting materials were melted in an electric furnace at 1500°C. After the raw material was sufficiently melted, a stirring blade made of platinum was inserted into the glass melt and the material was stirred for 1 hour. Thereafter, the stirring blade was removed, the resulting melt was left to stand for 3 hours, and then the melt was poured into a jig to obtain a glass block. Thereafter, the glass block was kept near the glass transition temperature of the glass for 2 hours, and then the glass block was annealed to remove warping.

[0051] The obtained glass block was sliced into a 2.5-inch disk shape having a thickness of approximately 1 mm, and the inner circumference and the outer circumference were cut as concentric circles using a cutter. Then, rough polishing and polishing were performed on both surfaces, cleaning was then performed to produce glass substrates of the working examples and comparative examples having the glass compositions shown in Tables 1 to 4 and having a thickness of 0.635 mm. The physical properties of the glass substrates produced in this manner were evaluated as will be described later. The results are shown in Tables 1 to 4.

[0052] Note that in Tables 1 to 4, "FM" indicates "$SiO_2+Al_2O_3+B_2O_3$", "Li_2O/R_2O" indicates "$Li_2O/(Li_2O+Na_2O+K_2O)$", and "MgO/RO" indicates "MgO/(MgO+CaO+SrO+BaO+ZnO)".

[0053] <Glass transition temperature (Tg)>

A glass transition temperature was measured by heating a glass sample that was adjusted in powder form (produced by crushing the glass substrates that were produced above) in a temperature range from room temperature to 900°C and at a temperature increase rate of 10°C/min using a differential calorimeter (product name: "EXSTAR6000", available from Seiko Instruments Inc.). The results are shown in the section "Tg" in Tables 5 to 8.

[0054] <Young's modulus and density>

Young's moduluses of the glass substrates that were produced above

were measured using a free resonance elastic modulus measuring apparatus (product name: "JE-RT", available from Nihon Techno-Plus Co., Ltd.) conforming to the dynamic elastic modulus testing method of the elasticity testing method of JIS R 1602 fine ceramics, and densities thereof were measured using an Archimedes method. The results are shown in Tables 5 to 8.

[0055] <Surface roughness>

Surface roughnesses of the glass substrates were measured using an atomic force microscope (AFM) (product name: "NanoscopeV", available from Veeco). A measurement range was set to 10 nm, and the case where the surface roughness of a square was 1.2 nm or less was evaluated as "A", and the case where the surface roughness thereof exceeds 1.2 nm was evaluated as "B". The results are shown in Tables 5 to 8.

[0056] <Fluttering>

Fluttering amounts of the glass substrates were measured using a laser Doppler displacement meter (product name: "OFV-151", available from Polytec Japan). Measurement was performed in an open space under atmospheric pressure, a single glass substrate was clamped from the above and below in the form of concentric circles at a position located 2 mm from the inner circumferential edge, the glass substrate was rotated at a rotation rate of 5400 rpm, and an amplitude in a direction perpendicular to the recording surface was measured. A measurement frequency bandwidth was set to 10 kHz, and by obtaining a frequency spectrum of the obtained amplitude, the case where the maximum value at 500 Hz or more was less than 1.1 nm was evaluated as "S", the case where the maximum value was 1.1 nm or more and was less than 1.2 nm was evaluated as "A", the case where the maximum value was 1.2 nm or more and was less than 1.6 nm was evaluated as "B", the case where the maximum value was 1.6 nm or more and was less than 1.8 nm was evaluated as "C", and the case where the maximum value was 1.8 nm or more was evaluated "D". The results are shown in the section "Fluttering" in Tables 5 to 8. As is

clear from Tables 5 to 8, it can be confirmed that a substrate having a high Young's modulus has a smaller fluttering amount (that is, fluttering characteristics are preferable).

[0057] <HDD test>

Film of a Fe-Pt alloy was formed on the glass substrates of the working examples and the comparative examples with a sputtering method, and magnetic film was then formed on surfaces of the glass substrates by performing heat treatment (600°C, 1 hour) to produce a magnetic recording medium. Then, this magnetic recording medium was incorporated in a hard disk drive (HDD), which is a magnetic recording drive, SNRs (signal-to-noise ratios) were checked using a read/write analyzer (product name: "RWA1632", available from GUZIK) and a spinstand (product name: "S1701MP", available from GUZIK), and a magnetic recording medium having an SNR of 20 dB or more was evaluated as "A", a magnetic recording medium having an SNR of 16 dB or more and less than 20 dB was evaluated as "B", and a magnetic recording medium having an SNR of less than 16 dB was evaluated as "C". The results are shown in the section "SNR" in Tables 5 to 8. It is shown that the heat resistance of glass substrates deteriorates in the order "A", "B", "C". This is because the heat treatment during manufacture of a magnetic recording medium has a correlation with the SNR.

[0058] [Table 1]

		Work. Ex.									
		1	2	3	4	5	6	7	8	9	10
Constituent components	SiO_2	62.2	62.2	65.2	62.2	62.2	62.2	62.2	64.2	62.2	63.2
	Al_2O_3	9.6	12.6	9.6	9.6	9.6	9.6	9.6	11.6	9.6	10.6
	B_2O_3	0	0	0	0	0	0	0	0	0	0
	Li_2O	4.5	4.5	4.5	4.5	4.5	6.5	4.5	4.5	6	5
	Na_2O	0.5	0.5	0.5	2.5	0.5	0.5	0.5	0.5	1.5	1
	K_2O	0	0	0	0	0	0	0	0	0	0
	MgO	18.6	15.6	15.6	16.6	16.6	16.6	16.6	14.6	14.6	14.6
	CaO	2.6	2.6	2.6	2.6	4.6	2.6	2.6	2.6	4.1	3.6
	SrO	0	0	0	0	0	0	0	0	0	0
	BaO	0	0	0	0	0	0	0	0	0	0
	ZnO	0	0	0	0	0	0	0	0	0	0
	ZrO_2	0	0	0	0	0	0	0	0	0	0
	CeO_2	0	0	0	0	0	0	0	0	0	0
	SnO_2	0	0	0	0	0	0	0	0	0	0
	TiO_2	2	2	2	2	2	2	4	2	2	2
	Nb_2O_5	0	0	0	0	0	0	0	0	0	0
	FM	71.8	74.8	74.8	71.8	71.8	71.8	71.8	75.8	71.8	73.8
	Total	100	100	100	100	100	100	100	100	100	100
Ratios	Li_2O/R_2O	0.90	0.90	0.90	0.64	0.90	0.93	0.90	0.90	0.80	0.83
	MgO/RO	0.88	0.86	0.86	0.86	0.78	0.86	0.86	0.85	0.78	0.80

unit of numerical values of constituent components is mol%

[0059] [Table 2]

		Work. Ex.									
		11	12	13	14	15	16	17	18	19	20
Constituent components	SiO_2	62.2	59.2	62.2	62.2	62.2	62.2	60.2	62.2	61.2	62.2
	Al_2O_3	6.6	9.6	9.6	9.6	9.6	9.6	7.6	9.6	8.6	6.6
	B_2O_3	0	0	0	0	0	0	0	0	0	3
	Li_2O	4.5	4.5	4.4	4.5	2.5	4.5	4.5	2.3	3.3	4.5
	Na_2O	0.5	0.5	0.2	0.5	0.5	0.5	0.5	0.2	0.2	0.5
	K_2O	0	0	0	0	0	0	0	0	0	0
	MgO	21.6	21.6	19	20.6	20.6	20.6	22.6	22.6	22.6	18.6
	CaO	2.6	2.6	2.6	0.6	2.6	2.6	2.6	1.1	2.1	2.6
	SrO	0	0	0	0	0	0	0	0	0	0
	BaO	0	0	0	0	0	0	0	0	0	0
	ZnO	0	0	0	0	0	0	0	0	0	0
	ZrO_2	0	0	0	0	0	0	0	0	0	0
	CeO_2	0	0	0	0	0	0	0	0	0	0
	SnO_2	0	0	0	0	0	0	0	0	0	0
	TiO_2	2	2	2	2	2	0	2	2	2	2
	Nb_2O_5	0	0	0	0	0	0	0	0	0	0
	FM	68.8	68.8	71.8	71.8	71.8	71.8	67.8	71.8	69.8	68.8
	Total	100	100	100	100	100	100	100	100	100	100
Ratios	Li_2O/R_2O	0.90	0.90	0.96	0.90	0.83	0.90	0.90	0.92	0.94	0.90
	MgO/RO	0.89	0.89	0.88	0.97	0.89	0.89	0.90	0.95	0.91	0.88

unit of numerical values of constituent components is mol%

[0060] [Table 3]

		Work. Ex.									
		21	22	23	24	25	26	27	28	29	30
Constituent components	SiO_2	62.2	62.2	62.2	62.2	62.2	62.2	62.2	62.2	66.8	58
	Al_2O_3	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	7.9	13
	B_2O_3	0	0	0	0	0	0	0	0	0	0
	Li_2O	3	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4	5.5
	Na_2O	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	K_2O	1.8	0	0	0	0	0	0	0	0	0
	MgO	18.6	17.1	17.1	17.1	17.6	17.6	17.6	17.6	17.8	19.4
	CaO	2.6	1.1	1.1	1.1	1.1	1.6	1.6	1.1	2	1.6
	SrO	0	3	0	0	0	0	0	0	0	0
	BaO	0	0	3	0	0	0	0	0	0	0
	ZnO	0	0	0	3	0	0	0	0	0	0
	ZrO_2	0	0	0	0	3	0	0	0	0	0
	CeO_2	0	0	0	0	0	2	0	0	0	0
	SnO_2	0	0	0	0	0	0	2	0	0	0
	TiO_2	2	2	2	2	1.5	2	2	1.5	1	2
	Nb_2O_5	0	0	0	0	0	0	0	3	0	0
	FM	71.8	71.8	71.8	71.8	71.8	71.8	71.8	71.8	74.7	71
	Total	100	100	100	100	100	100	100	100	100	100
Ratios	Li_2O/R_2O	0.60	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.89	0.92
	MgO/RO	0.88	0.81	0.81	0.81	0.94	0.92	0.92	0.94	0.90	0.92

unit of numerical values of constituent components is mol%

[0061] [Table 4]

		Comp. Ex.							
		1	2	3	4	5	6	7	8
Constituent components	SiO_2	64.8	58.2	58.2	59.2	65.2	60.5	64.7	66.5
	Al_2O_3	8.6	7.6	11.6	10.6	12.6	9.6	9.6	9.4
	B_2O_3	0	0	0	0	0	0	0	0
	Li_2O	5.8	6.5	3.5	4.5	2.5	6.5	4.5	6
	Na_2O	8.7	0.5	2.5	0.5	0.5	0.2	0.5	2.5
	K_2O	0.7	0	0	0	0	0	0	1.4
	MgO	7.2	20.6	17.3	15.1	16.6	18.6	18.6	8.7
	CaO	2.2	4.6	4.9	6.1	1.6	2.6	0.1	2.8
	SrO	0	0	0	0	0	0	0	0
	BaO	0	0	0	0	0	0	0	0
	ZnO	0	0	0	2	0	0	0	0
	ZrO_2	0	0	0	0	0	0	0	0
	CeO_2	0	0	0	0	0	0	0	0
	SnO_2	0	0	0	0	0	0	0	0
	TiO_2	2	2	2	2	1	2	2	2.7
	Nb_2O_5	0	0	0	0	0	0	0	0
	FM	73.4	65.8	69.8	69.8	77.8	70.1	74.3	75.9
	Total	100	100	100	100	100	100	100	100
Ratios	Li_2O/R_2O	0.38	0.93	0.58	0.90	0.83	0.97	0.90	0.61
	MgO/RO	0.77	0.82	0.78	0.65	0.91	0.88	0.99	0.76

unit of numerical values of constituent components is mol%

[0062] [Table 5]

	Work. Ex.									
	1	2	3	4	5	6	7	8	9	10
Tg (°C)	682	712	667	662	682	652	692	692	649.5	674.5
Young's modulus (GPa)	96.4	94.9	91.9	93.4	96.4	96.5	94.3	92.3	94.9	93.6
Density (g/cm^3)	2.55	2.52	2.49	2.53	2.55	2.53	2.55	2.49	2.525	2.51
Surface roughness	A	A	A	A	A	A	A	A	A	A
Fluttering	S	A	A	A	S	S	A	A	A	A
SNR	A	A	A	A	A	A	A	A	A	A

[0063] [Table 6]

	Work. Ex.									
	11	12	13	14	15	16	17	18	19	20
Tg (°C)	652	697	687	682	712	672	672	718	698	637
Young's modulus (GPa)	97.8	100.7	96.8	96.4	96.3	98.3	100.2	96.9	98.7	93.4
Density (g/cm^3)	2.58	2.61	2.55	2.55	2.57	2.55	2.61	2.58	2.60	2.55
Surface roughness	A	A	A	A	A	A	A	A	A	A
Fluttering	S	S	S	S	S	S	S	S	S	A
SNR	A	A	A	A	A	A	A	A	A	A

[0064] [Table 7]

	Work. Ex.									
	21	22	23	24	25	26	27	28	29	30
Tg (°C)	690	682	682	667	695	682	682	710	645	722
Young's modulus (GPa)	94.1	93.4	93.4	94.9	98.3	94.4	94.4	95.4	89.8	100.6
Density (g/cm^3)	2.55	2.52	2.52	2.58	2.61	2.53	2.53	2.67	2.48	2.59
Surface roughness	A	A	A	A	A	A	A	A	A	A
Fluttering	A	A	A	A	S	A	A	S	B	S
SNR	A	A	A	A	A	A	A	A	B	A

[0065] [Table 8]

	Comp. Ex.							
	1	2	3	4	5	6	7	8
Tg (°C)	571	-	718	697	-	664	-	636
Young's modulus (GPa)	78.6	-	98.4	99.4	-	99.3	-	84.2
Density (g/cm^3)	2.41	-	2.62	2.62	-	2.57	-	2.44
Surface roughness	A	-	A	A	-	A	-	A
Fluttering	D	-	C	C	-	C	-	C
SNR	C	-	C	C	-	C	-	C

[0066] As is clear from Tables 5 to 8, it was confirmed that compared to the glass substrates of the comparative examples, the glass substrates of the working examples had excellent heat resistance, exhibited higher Young's moduluses, and had the excellent effect of having lower densities.

[0067] The glass substrate of Comparative Example 1 had a low Young's modulus, and recording characteristics were not preferable due to the influence of fluttering. The glass substrates of Comparative Example 2 and Comparative Example 7 could not be evaluated due to difficulty in formation of glass from the material. The glass substrate of Comparative Example 5 could not be press-molded, and thus the substrate could not be evaluated either. The glass substrates of Comparative Example 3 and Comparative Example 4 had greater densities, and thus it was found that energy consumption accompanying rotation of the disks increases. The glass substrate of Comparative Example 6 had worse chemical resistance. The glass substrate of Comparative Example 8 had a low Young's modulus, and recording characteristics were not preferable due to the influence of fluttering.

[0068] Although an embodiment and working examples of the present invention have been described as above, it should be evident that the configurations of the above-described embodiment and working examples are used in combination as appropriate.

[0069] The disclosed embodiment and working examples are to be considered exemplary in all respects and in no way limiting. The scope of the present invention is defined by the scope of the appended claims and not by the above description, and all changes that fall within the same essential spirit as the scope of the claims are included therein.

CLAIMS

1. A glass substrate having a glass composition in which
in mol%, the following content ranges:
SiO_2: 58 to 67%;
Al_2O_3: 6.5 to 13%;
B_2O_3: 0 to 3%;
Li_2O: 2.3 to 6.5%;
Na_2O: 0.2 to 2.5%;
K_2O: 0 to 2%;
MgO: 14 to 23%;
CaO: 0.6 to 4.6%;
SrO: 0 to 3%;
BaO: 0 to 3%;
ZnO: 0 to 3%;
ZrO_2: 0 to 3%;
CeO_2: 0 to 2%;
SnO_2: 0 to 2%;
TiO_2: 0 to 4%; and
Nb_2O_5: 0 to 3% are satisfied, and
in mol%, the following condition:
$SiO_2+Al_2O_3+B_2O_3$: 67 to 76% is satisfied, and
the following ratios:
$0.6 \leq Li_2O/(Li_2O+Na_2O+K_2O) \leq 0.96$; and
$0.78 \leq MgO/(MgO+CaO+SrO+BaO+ZnO) \leq 0.98$ are satisfied.

2. The glass substrate according to claim 1, wherein
the glass substrate has a Young's modulus of 90 GPa or more and 101 GPa or less, and has a density of 2.49 g/cm^3 or more and 2.61 g/cm^3 or less.

3. The glass substrate according to claim 1 or 2, wherein

the glass substrate has a glass transition temperature of 635°C or more and 725°C or less.

4. The glass substrate according to any of claims 1 to 3, wherein

a thickness t (unit: mm) of the glass substrate and an outer diameter d (unit: mm) of the glass substrate are in the following relationship: $t/d \leq 0.011$.

5. The glass substrate according to any of claims 1 to 4, wherein

the glass substrate is a glass substrate for a magnetic recording medium.

6. The glass substrate according to any of claims 1 to 5, wherein

a surface of the glass substrate is subjected to chemical strengthening processing.