

DESCRIPTION

TITLE OF INVENTION

HDD Glass Substrate

5 TECHNICAL FIELD

The present invention relates to a HDD (hard disk drive) glass substrate.

BACKGROUND ART

In recent years, as the storage capacity of a HDD is exponentially increasing, it is essential to reduce a recording area for one bit in the medium. In proportion to the
10 reduction of the recording area, magnetic particles for recording need to have finer sizes. However, such finer sizes lead to small energy in maintaining the recorded direction of magnetization in one direction, with the result that the direction of magnetization is likely to be affected by heat energy, disadvantageously.

In order to stabilize the direction of magnetization, the material of the magnetic
15 particles need to be changed to an Fe-Pt-based magnetic material having high magnetic anisotropy energy. However, the Fe-Pt-based magnetic material has to be subjected to a high-temperature heat treatment during film formation in a production process for forming a recording medium.

Accordingly, a glass substrate for holding the magnetic material is also required
20 to have a high heat resistance. Generally, as such a glass substrate having a high heat resistance, glass substrates having various glass compositions have been proposed (Japanese Patent Laying-Open No. 2005-015328 (Patent Document 1), Japanese Patent Laying-Open No. 2005-314159 (Patent Document 2), and Japanese Patent Laying-Open No. 10-158028 (Patent Document 3)).

25 CITATION LIST

PATENT DOCUMENT

PTD 1: Japanese Patent Laying-Open No. 2005-015328

PTD 2: Japanese Patent Laying-Open No. 2005-314159

PTD 3: Japanese Patent Laying-Open No. 10-158028

SUMMARY OF INVENTION

TECHNICAL PROBLEM

Each of the proposed glass compositions having high heat resistances tends to have a high specific gravity and a low specific modulus of elasticity (E/ρ ; E : Young's modulus, ρ : specific gravity), thus adversely affecting a fluttering characteristic of the HDD.

The present invention has been made in view of the above-described current circumstance, and has an object to provide a HDD glass substrate having both an excellent heat resistance and an excellent fluttering characteristic by achieving both a high heat resistance and a high specific modulus of elasticity.

SOLUTION TO PROBLEM

A HDD glass substrate of the present invention is characterized in that it includes a glass composition having, by mol%, the following content range:

- 60% to 75% of SiO_2 ;
 - 0.1% to 6% of Al_2O_3 ;
 - 0% to 3% of B_2O_3 ;
 - 0.1% to 5% of Li_2O ;
 - 0.1% to 6% of Na_2O ;
 - 0.1% to 5% of K_2O ;
 - 5% to 18% of MgO ;
 - 0.1% to 10% of CaO ;
 - 0% to 5% of ZnO ;
 - 0% to 5% of TiO_2 ; and
 - 0.1% to 5% of ZrO_2 ,
- the glass composition satisfying the following conditions:
- $0.01 < (\text{ZrO}_2 + \text{TiO}_2)/(\text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{B}_2\text{O}_3) < 0.15$;
 - $0.1 < \text{Li}_2\text{O}/(\text{Li}_2\text{O} + \text{Na}_2\text{O} + \text{K}_2\text{O}) < 0.8$; and
 - $0.3 \text{ mol\%} < (\text{Li}_2\text{O} + \text{Na}_2\text{O} + \text{K}_2\text{O}) < 15 \text{ mol\%}$.

Here, the HDD glass substrate is preferably a HDD glass substrate for heat-

assisted recording.

The HDD glass substrate of the present invention preferably includes a glass composition having, by mol%, the following content range:

- 63% to 72% of SiO_2 ;
- 5 1% to 5% of Al_2O_3 ;
- 0% to 2% of B_2O_3 ;
- 1% to 4% of Li_2O ;
- 1% to 5% of Na_2O ;
- 0.1% to 4% of K_2O ;
- 10 8% to 15% of MgO ;
- 1% to 8% of CaO ;
- 0% to 3% of ZnO ;
- 0% to 3% of TiO_2 ; and
- 1% to 4% of ZrO_2 ,
- 15 the glass composition satisfying the following conditions:
0.03 < $(\text{ZrO}_2 + \text{TiO}_2)/(\text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{B}_2\text{O}_3) < 0.12$;
0.2 < $\text{Li}_2\text{O}/(\text{Li}_2\text{O} + \text{Na}_2\text{O} + \text{K}_2\text{O}) < 0.7$; and
2.1 mol% < $(\text{Li}_2\text{O} + \text{Na}_2\text{O} + \text{K}_2\text{O}) < 13$ mol%.

20 Further, the glass composition preferably contains no BaO. A chemical strengthening process is preferably performed during production of the HDD glass substrate.

ADVANTAGEOUS EFFECTS OF INVENTION

25 Because the HDD glass substrate of the present invention has the above-described configuration, the HDD glass substrate exhibits an excellent effect such that the HDD glass substrate has both an excellent heat resistance and an excellent fluttering characteristic by achieving both a high heat resistance and a high specific modulus of elasticity.

DESCRIPTION OF EMBODIMENTS

The following describes an embodiment according to the present invention

more in detail.

<HDD glass substrate>

A HDD glass substrate of the present invention is characterized in that it includes a glass composition having, by mol%, the following content range:

- 5 60% to 75% of SiO_2 ;
 0.1% to 6% of Al_2O_3 ;
 0% to 3% of B_2O_3 ;
 0.1% to 5% of Li_2O ;
 0.1% to 6% of Na_2O ;
10 0.1% to 5% of K_2O ;
 5% to 18% of MgO ;
 0.1% to 10% of CaO ;
 0% to 5% of ZnO ;
 0% to 5% of TiO_2 ; and

- 15 0.1% to 5% of ZrO_2 ,

the glass composition satisfying the following conditions:

$$0.01 < (\text{ZrO}_2 + \text{TiO}_2) / (\text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{B}_2\text{O}_3) < 0.15;$$

$$0.1 < \text{Li}_2\text{O} / (\text{Li}_2\text{O} + \text{Na}_2\text{O} + \text{K}_2\text{O}) < 0.8; \text{ and}$$

$$0.3 \text{ mol\%} < (\text{Li}_2\text{O} + \text{Na}_2\text{O} + \text{K}_2\text{O}) < 15 \text{ mol\%}. \quad \text{It should be noted that the}$$

- 20 symbol "%" for the glass composition in the present invention is intended to represent "mol%" unless otherwise stated. Moreover, a representation of addition of chemical formulas such as " $\text{ZrO}_2 + \text{TiO}_2$ " is intended to indicate a total amount of the components indicated by the chemical formulas. For example, " $\text{ZrO}_2 + \text{TiO}_2$ " indicates a total amount of ZrO_2 and TiO_2 .

- 25 Because the HDD glass substrate of the present invention has the above-described configuration, the HDD glass substrate exhibits an excellent effect such that the HDD glass substrate has both an excellent heat resistance and an excellent fluttering characteristic by exhibiting both a high heat resistance and a high specific modulus of elasticity. Such an excellent effect is attained by synergistically exhibiting the below-

described functions of the components of the glass composition.

It should be noted that the glass composition is preferably composed of only the above-described components except for an inevitable impurity. Regarding this point, one of features of the glass composition of the present invention lies in that it contains
5 no BaO. This is because if BaO is contained, the heat resistance is greatly decreased and the specific modulus of elasticity is also decreased, thus resulting in deterioration of the fluttering characteristic.

It should be noted that the fluttering characteristic and the specific modulus of elasticity have the following relations.

10 That is, first, the fluttering amount of the HDD glass substrate (disk) is increased when the natural vibration of the disk coincides with the frequency of force F acting due to airflow in the drive. Considering from the one-dimensional model of forced vibration, a fluttering amount X during resonance is expressed by:

[Formula 1]

15
$$\frac{X}{F} \propto \frac{1}{\omega_n} \quad (\omega_n : \text{natural vibration frequency})$$

Furthermore, it is generally known that natural vibration frequency ω_n is proportional to the 1/2nd power of the specific modulus of elasticity and natural vibration frequency ω_n is expressed by the following formula:

[Formula 2]

20
$$\omega_n \propto \sqrt{\frac{E}{\rho}}$$

Thus, it is understood that as specific modulus of elasticity E/ρ is higher, fluttering amount X of the disk can be reduced further. It should be noted that a more excellent fluttering characteristic means a smaller fluttering amount.

The HDD glass substrate of the present invention exhibiting the above-
25 described characteristic is particularly suitable for a HDD glass substrate for heat-assisted recording. This is due to the following reason. That is, the heat-assisted recording is to record information onto a magnetic recording medium while locally

heating the magnetic recording medium. In order to achieve a particularly high density recording, the use of the above-described Fe-Pt-based magnetic material is required, so that the glass substrate is also required to have a particularly high heat resistance.

5 It should be noted that the HDD glass substrate of the present invention preferably has a disk-like shape. Accordingly, the HDD glass substrate becomes suitable to be incorporated in a HDD. It should be noted that the size of the disk-like shape is not particularly limited when the HDD glass substrate has the disk-like shape. For example, the disk can have a small diameter such as 3.5 inches, 2.5 inches, or 1.8
10 inches or less and can have a thin thickness such as 2 mm, 1 mm, 0.8 mm, or 0.635 mm or less.

<Glass Composition>

The following describes each of the components of the glass composition of the present invention.

15 SiO_2 , which is a component of the glass composition of the present invention, is an important component to form a network structure of glass. The glass composition of the present invention contains 60% to 75% of SiO_2 . (Such a numerical range in the present invention is intended such that the lower limit value and the upper limit value are included in the range. Hence, the phrase "60% to 75%" indicates "not less than
20 60% and not more than 75%".)

If the content of SiO_2 is less than 60%, it becomes difficult to form glass and presumably result in deterioration of chemical durability. On the other hand, if the content is more than 75%, a melting temperature becomes too high. A more preferable content range of SiO_2 is 63% to 72%.

25 Al_2O_3 is an important component to form the network structure together with SiO_2 , and has a function of improving not only the heat resistance but also ion exchange performance. If the content of Al_2O_3 is less than 0.1%, the chemical durability or the ion exchange performance may be decreased. On the other hand, if the content is more than 6%, the ion exchange performance is decreased and the liquid

phase temperature and melting temperature are increased to result in decrease of moldability. Accordingly, the content range (content) of Al_2O_3 in the glass composition needs to fall within the range of 0.1% to 6%. In the range, a range of 1% to 5% is preferable.

5 B_2O_3 is an important component to form the network structure together with SiO_2 , and has a function of decreasing the melting temperature. Hence, B_2O_3 is contained as required. If the content of B_2O_3 is more than 3%, a T_g (glass transition point), which serves as an index for the heat resistance, is decreased. Hence, in order to attain a high T_g and an excellent heat resistance, the content range of B_2O_3 needs to
10 fall within a range of 0% to 3%. In the range, a range of 0% to 2% is preferable.

Li_2O has a function of improving the Young's modulus and therefore improving the specific modulus of elasticity due to its low specific gravity, and is also a component required for a chemical strengthening treatment employing ion exchange. In the chemical strengthening treatment, Li^+ ion in the glass composition are exchanged
15 with Na^+ ion or K^+ ion in a chemical strengthening treatment liquid, thereby strengthening the glass substrate. If the content of Li_2O is less than 0.1%, the effect of improving the Young's modulus cannot be obtained sufficiently and the ion exchange performance is decreased. On the other hand, if the content is more than 5%, the T_g is decreased. Hence, the content range of Li_2O needs to fall within a range of 0.1% to
20 5%. In the range, a range of 1% to 4% is preferable.

Na_2O is a component required for the chemical strengthening treatment employing ion exchange. In the chemical strengthening treatment, the glass substrate is strengthened by ion exchange between the Na^+ ion in the glass composition and the K^+ ion in the chemical strengthening treatment liquid. If the content of Na_2O is less
25 than 0.1%, the ion exchange performance is decreased and meltability and devitrification resistance are deteriorated. On the other hand, if the content is more than 6%, the chemical durability is decreased. Hence, the content range of Na_2O needs to fall within a range of 0.1% to 6%. In the range, a range of 1% to 5% is preferable.

K₂O has an effect of improving the meltability. If the content of K₂O is less than 0.1%, the effect of improving the meltability cannot be obtained. On the other hand, if the content is more than 5%, the T_g is decreased and the Young's modulus is also decreased. Hence, the content range of K₂O falls within a range of 0.1% to 5%.

5 In the range, a range of 0.1% to 4% is preferable.

In the present invention, a total amount of Li₂O, Na₂O, and K₂O (Li₂O + Na₂O + K₂O) needs to be in the range of more than 0.3 mol% and less than 15 mol%. If the total amount is not more than 0.3%, the effect of improving the meltability cannot be obtained sufficiently and also the alkali mixing effect cannot be obtained to result in
10 decrease of chemical durability. On the other hand, if the total amount is not less than 15%, the T_g is decreased to result in an insufficient heat resistance. A more preferable range is more than 2.1% and less than 13%.

MgO has effects of increasing the Young's modulus and improving the meltability. If the content of MgO is less than 5%, the effect of increasing the
15 Young's modulus and the effect of improving the meltability cannot be obtained. On the other hand, if the content is more than 18%, the glass structure becomes unstable to result in deterioration of the devitrification resistance. For this reason, the content range of MgO falls within a range of 5% to 18%. In the range, a range of 8% to 15% is preferable.

20 CaO has effects of increasing a linear thermal expansion coefficient and the Young's modulus and improving the meltability. If the content of CaO is less than 0.1%, the effect of increasing the linear thermal expansion coefficient and the Young's modulus cannot be obtained sufficiently. On the other hand, if the content is more than 10%, the glass structure becomes unstable to result in deterioration of the
25 devitrification resistance. Therefore, the content range of CaO falls within a range of 0.1% to 10%. In the range, a range of 1% to 8% is preferable.

Because ZnO has effects of increasing the Young's modulus and improving the meltability, ZnO is contained as required. If the content of ZnO is more than 5%, the glass structure becomes unstable to result in deterioration of the devitrification

resistance. Therefore, the content range of ZnO falls within a range of 0% to 5%. In the range, a range of 0% to 3% is preferable.

Because TiO_2 has effects of softening a high temperature viscosity and increasing rigidity, TiO_2 is contained as required. However, if the content of TiO_2 is more than 5%, the devitrification resistance is deteriorated. Therefore, the content range of TiO_2 falls within a range of 0% to 5%. In the range, a range of 0% to 3% is preferable.

ZrO_2 has effects of improving the heat resistance and improving the Young's modulus. If the content of ZrO_2 is less than 0.1%, the effect of improving the heat resistance and the effect of improving the Young's modulus cannot be obtained sufficiently. If the content is more than 5%, the devitrification resistance is deteriorated. Therefore, the content range of ZrO_2 falls within a range of 0.1% to 5%. In the range, a range of 1% to 4% is preferable.

In the present invention, it is important that the ratio between the total amount of ZrO_2 and TiO_2 and the total amount of SiO_2 , Al_2O_3 and B_2O_3 ($(\text{ZrO}_2 + \text{TiO}_2)/(\text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{B}_2\text{O}_3)$) is in the range of more than 0.01 and less than 0.15. This ratio represents a ratio of the components for improving the rigidity and heat resistance of the glass to the skeleton components of the glass. If the ratio is equal to or less than 0.01, sufficient rigidity and heat resistance cannot be obtained. On the other hand, if the ratio is equal to or more than 0.15, the specific gravity becomes too large. Accordingly, the specific modulus of elasticity is decreased and the glass structure becomes unstable to result in decrease of chemical durability and fracture toughness. This ratio is more preferably in the range of more than 0.03 and less than 0.12.

Further, in the present invention, the ratio of Li_2O to the total amount of Li_2O , Na_2O and K_2O ($\text{Li}_2\text{O}/(\text{Li}_2\text{O} + \text{Na}_2\text{O} + \text{K}_2\text{O})$) needs to be in the range of more than 0.1 and less than 0.8. This ratio is a ratio of Li_2O to the total amount of the alkali components. If the ratio is equal to or less than 0.1, a sufficient specific modulus of elasticity cannot be obtained. On the other hand, if the ratio is equal to or more than 0.8, a sufficient heat resistance cannot be obtained. This ratio is more preferably in

the range of more than 0.2 and less than 0.7.

As apparent from the explanation for each of the components described above, the glass composition of the present invention is characterized in that each of the components is contained therein in the specific range and the content ratio of the specific ones of the components are in the specific range, thereby improving the heat resistance and the specific modulus of elasticity in a balanced manner. Hence, the glass composition of the present invention can exhibit a characteristic such that the T_g becomes 650°C or more and the specific modulus of elasticity becomes 32.0 GPa·cm³/g or more. Therefore, the HDD glass substrate including the glass composition of the present invention exhibits an excellent heat resistance and an excellent fluttering characteristic.

<Suitable Composition>

As described above, the HDD glass substrate of the present invention preferably includes a glass composition having, by mol%, the following content range:

63% to 72% of SiO₂;

1% to 5% of Al₂O₃;

0% to 2% of B₂O₃;

1% to 4% of Li₂O;

1% to 5% of Na₂O;

0.1% to 4% of K₂O;

8% to 15% of MgO;

1% to 8% of CaO;

0% to 3% of ZnO;

0% to 3% of TiO₂; and

1% to 4% of ZrO₂,

the glass composition satisfying the following conditions:

$0.03 < (\text{ZrO}_2 + \text{TiO}_2) / (\text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{B}_2\text{O}_3) < 0.12$;

$0.2 < \text{Li}_2\text{O} / (\text{Li}_2\text{O} + \text{Na}_2\text{O} + \text{K}_2\text{O}) < 0.7$; and

$2.1 \text{ mol\%} < (\text{Li}_2\text{O} + \text{Na}_2\text{O} + \text{K}_2\text{O}) < 13 \text{ mol\%}$. This can be a suitable

embodiment of the present invention.

<Production Method>

A method of producing the HDD glass substrate of the present invention is not particularly limited and a conventionally known production method can be employed.

5 For example, as a raw material for each of the components of the glass composition of the HDD glass substrate, a relevant oxide, a relevant carbonate, a relevant nitrate, a relevant hydroxide, or the like is employed. They are measured in a desired ratio, and are mixed sufficiently in the form of powders, thereby obtaining a prepared raw material.

10 Then, the prepared raw material is introduced into a platinum crucible or the like in an electric furnace heated to, for example, 1300°C to 1550°C, is melted and becomes clear, thereafter is stirred and becomes uniform, is poured into a mold heated in advance, and then is gradually cooled, thereby obtaining a glass block. Next, the glass block is held for 1 hour to 3 hours at a temperature around the glass transition
15 point, and is then gradually cooled to remove strain.

Next, the glass block thus obtained is sliced into a disk shape, and is cut using a core drill such that the inner circumference and outer circumference thereof become concentric circles. Alternatively, the molten glass is pressed into a disk-like shape. The disk-like glass substrate thus obtained is then subjected to rough polishing and
20 precision polishing for both sides thereof, and then is cleaned using at least one liquid of water, acid, and alkali. In this way, a final HDD glass substrate is obtained.

It should be noted that in course of the above-described processes, after the rough polishing and precision polishing for the both sides, the glass substrate can be immersed in a mixed solution of potassium nitrate (50 wt%) and sodium nitrate (50
25 wt%) to chemically strengthen a surface of the glass substrate. Alternatively, the chemical strengthening may be performed before the rough polishing or the precision polishing and then the ion exchange layer may be removed in either of the polishing processes (in this case, however, the ion exchange layer still remains at the end surface thereof).

Such an operation of immersing the glass substrate (precursor) in the solution including alkali is generally called a "chemical strengthening process", and is an ion exchange process in which alkali metal ions such as lithium ion or sodium ion in the glass substrate precursor are replaced with alkali metal ions each having a larger ionic radius such as potassium ion. Strain resulting from the difference in ionic radius provides compressive stress generated centrally at the region having been through the ion exchange, thereby strengthening the surface of the glass substrate precursor in the region. An example of such a chemical strengthening treatment liquid is the above-described solution containing nitrate.

Such a chemical strengthening process is preferably performed during the production of the HDD glass substrate of the present invention. It should be noted that the chemical strengthening process is performed before or after the rough polishing and precision polishing processes in the above description, but there is no particular limitation as to in what stage the chemical strengthening process is to be performed during the production process. Further, the ion exchange layer formed by the chemical strengthening process as described above may remain in the final glass substrate or may be removed. In the case where the ion exchange layer remains, the composition of the layer may differ from the glass composition of the present invention, but the glass composition of the present invention assumes portions other than the ion exchange layer.

It should be noted that after the HDD glass substrate of the present invention is produced using the above-described production method, a magnetic layer (magnetic film) serving as a recording layer is formed, thereby obtaining an information recording medium (magnetic recording medium). This information recording medium can be incorporated in a HDD and can be used.

[Examples]

In the following, the present invention will be described in more detail in connection with Examples. The present invention, however, is not limited to them.

<Examples 1 to 10 and Comparative Examples 1 to 7>

In order to obtain each of glass compositions illustrated in Table 1 and Table 2 below, predetermined amounts of raw material powders were measured, were introduced into a platinum crucible, were mixed, and were then melted in an electric furnace at 1550°C. After the raw materials were sufficiently melted, a stirring blade made of platinum was inserted into the glass melt to stir it for 1 hour.

Thereafter, the stirring blade was removed and then the glass melt was left for 30 minutes. Then, the glass melt was flown into a jig, thereby obtaining a glass block. Thereafter, the glass block was held for 2 hours at a temperature around the glass transition point (T_g) for each glass, and thereafter was gradually cooled to remove strain.

Next, the glass block thus obtained was sliced into a 2.5-inch disk shape having a thickness of about 1.5 mm, and was cut using a cutter such that the inner circumference and outer circumference thereof became concentric circles. Then, both sides thereof were subjected to the rough polishing and the precision polishing, and then cleaning was performed. In this way, the HDD glass substrate of each of the examples and the comparative examples was fabricated. It should be noted that the HDD glass substrate of each of the comparative examples does not have the glass composition of the present invention.

Evaluation on physical properties was made as described below with regard to each of the HDD glass substrates thus fabricated, and below-described tests (a heat resistance test and a drive test) were performed. Results of these are shown in Table 1 and Table 2 below.

<Glass Transition Point (T_g)>

A differential thermal measurement device (trademark: "EXSTAR6000" provided by Seiko Instruments Inc.) was used to heat the glass sample, which had been prepared in the form of powders, at a temperature increasing rate of 10°C/min within a temperature range from a room temperature to 900°C and perform measurement, thereby measuring the glass transition point.

<Specific Modulus of Elasticity (E/ρ)>

Young's modulus E was measured in accordance with a dynamic elastic modulus testing method of testing methods for elastic modulus of fine ceramics in JIS R 1602. Meanwhile, in accordance with the Archimedes method, specific gravity ρ was measured. From these measured values, specific modulus of elasticity E/ρ was calculated.

<Heat Resistance Test>

The HDD glass substrate of each of the examples and the comparative examples was subjected to a heat treatment for 1 hour in an atmosphere at 650°C, and was then checked as to whether or not each of the HDD glass substrates was deformed.

The check for deformation was performed by measuring a degree of flatness of the glass substrate using a white light interference type surface shape measuring instrument (trademark: "Optiflat" provided by Phase Shift Technology). Then, evaluation was made as follows: a case where the degree of flatness was not more than 5 μm was regarded as "A"; a case where the degree of flatness was more than 5 μm and less than 50 μm was regarded as "B"; and a case where the degree of flatness was not less than 50 μm was regarded as "C". A degree of flatness smaller in numerical value represents a more flat substrate and indicates a more excellent heat resistance.

It should be noted that the heat treatment condition employed in the present test was assumed to be employed for a condition in forming a film of a Fe-Pt-based magnetic material having high magnetic anisotropy energy.

<Drive Test>

On the HDD glass substrate of each of the examples and the comparative examples, a Co-Cr magnetic layer was formed based on a conventional method to fabricate a magnetic recording medium (magnetic disk). Then, it was checked whether or not a reading error took place due to TMR (Track MisRegistration) when this magnetic disk was mounted on a HDD and was rotated for 5 minutes at a high speed of 15000 rpm. The TMR is such that the magnetic head is displaced from a signal read position due to fluctuation of the magnetic disk.

Then, evaluation was made as follows: occurrence of no error was regarded as

"A"; occurrence of not less than one and less than five errors was regarded as "B"; and occurrence of five or more errors was regarded as "C". Fewer errors represent a more excellent fluttering characteristic.

[Table 1]

	Unit	Example 1	Example 2	Example 3	Example 4	Example 5	Example 6	Example 7	Example 8	Example 9	Example 10
SiO ₂	mol%	66.9	65.4	70.3	65.9	66.9	66.9	74.4	66.9	62.9	60.4
Al ₂ O ₃	mol%	3.1	4.6	3.1	3.1	3.1	3.1	1.1	3.1	3.1	5.9
B ₂ O ₃	mol%	0.5	0.5	0.5	0.5	0.5	0.5	0.0	0.5	0.5	2.5
Li ₂ O	mol%	2.4	2.4	2.4	2.4	4.4	3.4	3.9	2.4	2.4	2.4
Na ₂ O	mol%	4.1	4.1	4.1	4.1	2.1	4.1	4.6	4.1	4.1	4.1
K ₂ O	mol%	1.3	1.3	1.3	1.3	1.3	0.3	4.3	4.3	1.3	1.3
MgO	mol%	11.9	11.9	8.5	11.9	11.9	11.9	5.4	8.9	11.9	13.6
CaO	mol%	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	8.8	4.8
ZnO	mol%	0.5	0.5	0.5	0.5	0.5	0.5	0.0	0.5	0.5	0.5
TiO ₂	mol%	1.0	1.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0
ZrO ₂	mol%	3.5	3.5	3.5	4.5	3.5	3.5	1.5	3.5	3.5	3.5
(ZrO ₂ +TiO ₂) / (SiO ₂ +Al ₂ O ₃ +B ₂ O ₃)	-	0.06	0.06	0.06	0.08	0.06	0.06	0.02	0.06	0.07	0.07
Li ₂ O / (Li ₂ O+Na ₂ O+K ₂ O)	-	0.31	0.31	0.31	0.31	0.56	0.44	0.30	0.22	0.31	0.31
Li ₂ O+Na ₂ O+K ₂ O	mol%	7.8	7.8	7.8	7.8	7.8	7.8	12.8	10.8	7.8	7.8
Total	mol%	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Glass Transition Point	°C	672	683	670	681	653	655	658	651	661	682
Young's Modulus	GPa	87	89	83	89	92	91	83	83	93	91
Specific Gravity	g/cm ³	2.55	2.57	2.55	2.60	2.54	2.55	2.44	2.54	2.57	2.60
Specific Modulus of Elasticity	GPa·cm ³ /g	34.1	34.6	32.5	34.2	36.2	35.7	34.0	32.7	36.2	35.0
Heat Resistance Test	-	A	A	A	A	A	A	A	A	A	A
Drive Test	-	A	A	A	A	A	A	A	A	A	A

[Table 2]

	Unit	Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5	Comparative Example 6	Comparative Example 7
SiO ₂	mol%	64.9	62.4	59.4	71.4	66.9	66.9	61.9
Al ₂ O ₃	mol%	3.1	3.1	3.1	3.1	3.1	10.1	3.1
B ₂ O ₃	mol%	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Li ₂ O	mol%	2.4	2.4	5.4	2.4	0.0	2.4	2.4
Na ₂ O	mol%	6.1	8.6	8.6	4.1	5.3	1.1	4.1
K ₂ O	mol%	1.3	1.3	1.3	1.3	2.5	1.3	6.3
MgO	mol%	11.9	11.9	11.9	11.9	11.9	11.9	11.9
CaO	mol%	4.8	4.8	4.8	4.8	4.8	0.8	4.8
ZnO	mol%	0.5	0.5	0.5	0.5	0.5	0.5	0.5
TiO ₂	mol%	1.0	1.0	1.0	0.0	1.0	1.0	1.0
ZrO ₂	mol%	3.5	3.5	3.5	0.0	3.5	3.5	3.5
(ZrO ₂ +TiO ₂) / (SiO ₂ +Al ₂ O ₃ +B ₂ O ₃)	-	0.07	0.07	0.07	0.00	0.06	0.06	0.07
Li ₂ O / (Li ₂ O+Na ₂ O+K ₂ O)	-	0.24	0.20	0.35	0.31	0.00	0.50	0.19
Li ₂ O+Na ₂ O+K ₂ O	mol%	9.8	12.3	15.3	7.8	7.8	4.8	12.8
Total	mol%	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Glass Transition Point	°C	648	630	601	637	685	-	628
Young's Modulus	GPa	85	83	87	81	76	-	80
Specific Gravity	g/cm ³	2.56	2.57	2.57	2.55	2.56	-	2.55
Specific Modulus of Elasticity	GPa·cm ³ /g	33.2	32.3	33.9	31.8	29.7	-	31.4
Heat Resistance Test	-	B	C	C	C	A	-	C
Drive Test	-	A	A	A	B	C	-	B

It should be noted that in Table 2, sections in comparative example 6 for the heat resistance test, the drive test, and the like are blank because each of the tests could not be performed due to the following reason. That is, the content of Al_2O_3 in the glass composition was high, so that the melting temperature became high to increase the viscosity in the melted state, with the result that the glass substrate could not be molded.

As apparent from Table 1 and Table 2, the HDD glass substrate of each of the examples had more excellent results in both the heat resistance test and the drive test than those of the HDD glass substrate of each of the comparative examples. Thus, it was confirmed that the HDD glass substrate of the present invention had both an excellent heat resistance and an excellent fluttering characteristic.

Heretofore, the embodiments and examples of the present invention have been illustrated, but it has been initially expected to appropriately combine the configurations of the embodiments and examples.

The embodiments and examples disclosed herein are illustrative and non-restrictive in any respect. The scope of the present invention is defined by the terms of the claims, rather than the embodiments described above, and is intended to include any modifications within the scope and meaning equivalent to the terms of the claims.

CLAIMS

1. A HDD glass substrate comprising a glass composition having, by mol%,
the following content range:
- 5 60% to 75% of SiO₂;
 0.1% to 6% of Al₂O₃;
 0% to 3% of B₂O₃;
 0.1% to 5% of Li₂O;
 0.1% to 6% of Na₂O;
10 0.1% to 5% of K₂O;
 5% to 18% of MgO;
 0.1% to 10% of CaO;
 0% to 5% of ZnO;
 0% to 5% of TiO₂; and
15 0.1% to 5% of ZrO₂,
 said glass composition satisfying the following conditions:
 $0.01 < (\text{ZrO}_2 + \text{TiO}_2) / (\text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{B}_2\text{O}_3) < 0.15$;
 $0.1 < \text{Li}_2\text{O} / (\text{Li}_2\text{O} + \text{Na}_2\text{O} + \text{K}_2\text{O}) < 0.8$; and
 $0.3 \text{ mol\%} < (\text{Li}_2\text{O} + \text{Na}_2\text{O} + \text{K}_2\text{O}) < 15 \text{ mol\%}$.
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2. The HDD glass substrate according to claim 1, wherein said HDD glass
substrate is a HDD glass substrate for heat-assisted recording.
3. The HDD glass substrate according to claim 1 or 2, comprising a glass
25 composition having, by mol%, the following content range:
 63% to 72% of SiO₂;
 1% to 5% of Al₂O₃;
 0% to 2% of B₂O₃;
 1% to 4% of Li₂O;

1% to 5% of Na_2O ;
0.1% to 4% of K_2O ;
8% to 15% of MgO ;
1% to 8% of CaO ;
5 0% to 3% of ZnO ;
0% to 3% of TiO_2 ; and
1% to 4% of ZrO_2 ,
said glass composition satisfying the following conditions:
 $0.03 < (\text{ZrO}_2 + \text{TiO}_2)/(\text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{B}_2\text{O}_3) < 0.12$;
10 $0.2 < \text{Li}_2\text{O}/(\text{Li}_2\text{O} + \text{Na}_2\text{O} + \text{K}_2\text{O}) < 0.7$; and
 $2.1 \text{ mol\%} < (\text{Li}_2\text{O} + \text{Na}_2\text{O} + \text{K}_2\text{O}) < 13 \text{ mol\%}$.

4. The HDD glass substrate according to any one of claims 1 to 3, wherein
said glass composition contains no BaO .

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5. The HDD glass substrate according to any one of claims 1 to 4, wherein a
chemical strengthening process is performed during production of said HDD glass
substrate.