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DESCRIPTION

SUBSTRATE FOR AN INFORMATION RECORDING MEDIUM

Technical Field

This invention relates to a disk substrate (will hereinafter be referred to as "a substrate for an information recording medium") for use in an information recording medium, such as a magnetic disk, an optical disk, and a magnetooptic disk as well as an information recording medium and, in particular, to a glass substrate for an information recording medium as well as an information recording medium using the above-mentioned substrate.

Background Art

As a substrate for an information recording medium, use is made of an aluminum substrate, an amorphous glass substrate (will simply be referred to as "a glass substrate" hereinafter), and a crystallized glass substrate. Among these substrates, the glass substrate is gradually expanding its market share because high surface smoothness (small surface roughness Ra) is easily obtained as compared with the other substrates and its strength is sufficient to withstand a reduction in thickness and size.

Among the above-mentioned glass substrates, a chemically strengthened glass substrate with its surface chemically strengthened by ion exchange is widely known in the art. Such a chemically strengthened glass substrate

may comprise a glass substance including 60.0-70.0 wt% of SiO_2 , 0.5-14.0 wt% of Al_2O_3 , 10.0-32.0 wt% of alkali metal oxide, 1.0-15.0 wt% of ZnO , and 1.1-14.0 wt% of B_2O_3 and having a linear expansion coefficient, pressure strength, and transverse rupture strength which are not smaller than specific values, respectively (see Japanese Patent Publication (JP-B) No. 4-70262).

As a material for preparing the chemically strengthened glass substrate, use is made of glass substances (a) and (b) mentioned below.

(a) A glass substance including 55-62 wt% of SiO_2 , 10-18 wt% of Al_2O_3 , 2-10 wt% of ZrO_2 , 2-5 wt% of MgO , 0.1-3 wt% of BaO , 12-15 wt% of Na_2O , 2-5 wt% of K_2O , 0-7 wt% of P_2O_5 , and 0.5-5 wt% of TiO_2 , where the total amount of Al_2O_3 and TiO_2 is 13-20 wt% (see Japanese Unexamined Patent Publication (JP-A) No. 1-167245).

(b) A glass substance including 64-70 wt% of SiO_2 , 14-20 wt% of Al_2O_3 , 4-6 wt% of Li_2O , 7-10 wt% of Na_2O , 0-4 wt% of MgO , and 0-1.5 wt% of ZrO_2 (see Japanese Patent Publication (JP-B) No. 6-76224).

As regards a hard disk apparatus, technical innovations are being made day by day in order to keep the superiority to other recording/reproducing apparatuses using information recording media such as an optical recording medium and a magneto-optic recording medium. One of the technical innovations is to rotate the magnetic disk at a high speed. Such high speed rotation is one attempt

to increase an access speed of a recording/reproducing magnetic head. The rotation speed is expected to exceed 10000 rpm hereafter, although it has been restricted to 5000-7000 rpm in the prior art.

As described above, the magnetic disk is desired to be rotated at a high speed. If the high speed rotation is sought by the use of the conventional glass substrate (glass substrate for an information recording medium), it is difficult to keep a stable flying height (the distance between the magnetic head and the magnetic disk upon recording and reproducing operations).

A need thus exists to provide a substrate for an information recording medium, which is easy in obtaining an information recording medium adapted to high speed rotation.

A need also exists to provide an information recording medium which is easy in obtaining a recording/reproducing apparatus having a high access speed.

A need further exists to provide an information recording medium which can simultaneously accomplish a high Young's modulus and a low flying height.

A need further exists to provide an information recording medium which has a high Young's modulus so as to suppress the vibration following the rotation.

Disclosure of the Invention

The present inventors have made extensive studies to reveal the cause of the difficulty in keeping the stable flying height when the above-mentioned high speed rotation is attempted by the use of the conventional glass substrate (glass substrate for an information recording medium). As a result, it has been found out that, when the information recording medium is rotated at a high speed, the information recording medium is deformed due to resonance to make it difficult to keep the stable flying height. It has also been found out that, in order to prevent the deformation of the information recording medium due to resonance when the information recording medium is rotated at a high speed, it is preferred to increase the Young's modulus of the substrate for an information recording medium.

As the substrate for an information recording medium having a high Young's modulus, a crystallized glass substrate is known. In the crystallized glass substrate, however, the strength and the Young's modulus are controlled by its crystallinity. Therefore, in order to increase the strength and the Young's modulus, the ratio of crystals is increased. As a result, it is difficult to obtain the surface smoothness (the surface roughness R_a) required to the information recording medium. Thus, it is difficult to assure a stable flying height even if the high speed rotation is attempted by the use of the crystallized glass substrate.

According to aspects of the present invention, it is possible to obtain, by the use of a glass (amorphous glass), a substrate for an information recording medium adaptable to the above-mentioned high-speed rotation. The substrate for an information recording medium according to this invention can be classified into first through sixth aspects. Among those, the first through the fourth aspects are common in the Young's modulus and the liquidus temperature. The substrate for an information recording medium according to each of the first through the sixth aspects forms a first embodiment.

(1) A substrate (will be referred to as "a glass substrate I" hereinafter) for an information recording medium, comprising a glass substance having the Young's modulus not smaller than 100GPa and the liquidus temperature not higher than 1350 °C.

(2) A substrate (will be referred to as "a glass substrate II" hereinafter) for an information recording medium, comprising a glass substance at least including TiO_2 and CaO as glass components, the contents of TiO_2 and CaO being selected so that the Young's modulus is not smaller than 100GPa and the liquidus temperature is not higher than 1350 °C.

(3) A substrate (will be referred to as "a glass substrate III" hereinafter) for an information recording medium, comprising a glass substance at least including TiO_2 and CaO as glass components, the contents of TiO_2 and CaO being selected so that the Young's modulus is not smaller than 100GPa, the liquidus temperature is not higher than 1350 °C, and the viscosity is not smaller than 10 poises in a formable temperature range.

(4) A substrate (will be referred to as "a glass substrate IV" hereinafter) for an information recording medium, comprising a glass substance including, as glass components, TiO_2 , CaO , MgO , and Al_2O_3 with at least Li_2O or Na_2O and Li_2O , the contents of the above-mentioned glass components being selected so that the Young's modulus is not smaller than 100GPa, the liquidus temperature is not higher than 1350 °C, the viscosity is not smaller than 10 poises in a formable temperature range, and the specific gravity is not greater than 3.5 g/cm³.

(5) A substrate (will be referred to as "a glass substrate V" hereinafter) for an information recording medium, comprising a glass substance including as glass components 0.1-30 mol% of TiO_2 , 1-45 mol% of CaO , 5-40 mol% of ($\text{MgO}+\text{CaO}$), 3-30 mol% of ($\text{Na}_2\text{O}+\text{Li}_2\text{O}$), 0-less than 15 mol% of Al_2O_3 , and 35-60 mol% of SiO_2

(6) A substrate (will be referred to as "a glass substrate VI" hereinafter) for an information recording medium, which is obtained by chemically strengthening one of the above-mentioned glass substrates I through V or the glass substance thereof.

According to a preferred embodiment of the present invention, an information recording medium comprises any one of the above-mentioned glass substrates I through VI and a recording layer formed on the glass substrate.

It is also possible to obtain a substrate for an information recording medium according to each of the seventh through ninth aspects of the present invention, which are different from the first through the sixth aspects. Specifically, the substrate for an information recording medium according to the seventh aspect essentially includes coexistence of Y_2O_3 and TiO_2 while the substrate for an information recording medium according to the eighth aspect includes coexistence of TiO_2 , Y_2O_3 , and ZrO_2 . The substrate for an information recording medium according to the ninth aspect includes TiO_2 and at least one oxide selected from a group consisting of Er_2O_3 , Nd_2O_3 , Sm_2O_3 , Eu_2O_3 , Gd_2O_3 , Tb_2O_3 , Dy_2O_3 , and Yb_2O_3 . The substrate for an information recording medium according to each of the seventh through the ninth aspects forms a second embodiment of this invention.

The substrate for an information recording medium or the medium according to each of the first and the second embodiments has a glass transition point not higher than 650 °C, preferably, not higher than 550 °C. The above-mentioned glass transition point is a comparatively low temperature.

Such a comparatively low glass transition point is effective in suppressing a damage during chemical strengthening. More specifically, upon the chemical strengthening, the glass substrate is typically immersed in fused salt. During the chemical strengthening, the fused salt is kept at a temperature 100-150 °C lower than the

glass transition point of the glass substrate. However, the fused salt starts to decompose at a temperature not lower than 500 °C. The fused salt thus decomposed damages the surface of the glass substrate. Taking the above into consideration, it is desired that the glass transition point is not higher than 650 °C, preferably, not higher than 550 °C in order to prevent the damage on the glass substrate. Thus, in order to accomplish such a comparatively low glass transition point, alkali components such as Na₂O and Li₂O and alkaline earth components such as MgO and CaO are added.

Brief Description of the Drawing

Fig. 1 shows the relationship between the Young's modulus and the vibration of a disk comprising an information recording medium.

Best Mode of Embodying the Invention

Description will now be made as regards an information recording medium and a substrate for an information recording medium according to a first embodiment of this invention.

At first, description will be made about the glass substrate I according to the first aspect in the first embodiment of this invention.

As described above, the glass substrate I of this invention comprises a glass substance having the Young's modulus not smaller than 100GPa and the liquidus

temperature not higher than 1350°C. Herein, "the glass substrate" referred to in this invention means a substrate comprising a glass (amorphous glass) substance which is substantially free from crystal grains. Thus, the above-mentioned "glass" is essentially different from crystallized glass or glass ceramics containing crystal grains.

As described above, it is desired to increase the Young's modulus of the glass substrate in order to prevent the glass substrate from being deformed due to resonance when the glass substrate of a reduced thickness is rotated at a high speed. For example, consideration will be made about the case where a magnetic disk prepared from a glass substrate having the diameter of 3.5 inches and the thickness of 0.635 mm (25 mil: this is a typical thickness for current magnetic disk substrates) is rotated at 10000rpm (hereinafter, the above-mentioned case will be referred to as "Case A"). In this case, in order that a stable flying height generally not greater than 1 μ m is kept between the magnetic disk and the recording/reproducing head and that vibration during rotation can be suppressed, it is preferred that the Young's modulus of the glass substrate is not smaller than 100GPa.

Furthermore, in order to obtain the glass substrate specified in this invention, it is required that substantially no crystal is precipitated during the manufacturing process. To this end, various steps such as melting, forming, and cooling of the material performed in

manufacturing of the glass substrate must be carried out at temperatures not lower than the liquidus temperature of the glass substance. Note that, if the liquidus temperature is extremely high, manufacture of the glass substrate itself is difficult so that the practicability is lost.

In view of the above, in the glass substrate I of this invention, the glass substance has the Young's modulus not smaller than 100GPa and the liquidus temperature not higher than 1350°C. Preferably, the Young's modulus is not smaller than 105GPa. Preferably, the liquidus temperature is not higher than 1250°C, more preferably, not higher than 1150°C.

Even if the Young's modulus of the glass substrate or the glass substance is not smaller than 100GPa, deflection of the magnetic disk in the case A is liable to exceed 2 μ m at maximum in case where the value (hereinafter called "a specific modulus") obtained by dividing the Young's modulus by the specific gravity of the glass substrate is not greater than about 30×10^6 Nm/kg. As a result, it is difficult to secure a stable flying height not greater than about 1 μ m. In this connection, the specific gravity of the glass substrate I of this invention is preferably not greater than about 3.5g/cm³, more preferably, not greater than 3.0g/cm³. Although the specific gravity is desired to be as low as possible, silicate-based glass has a value substantially not smaller than 2.1g/cm³.

Even if the liquidus temperature of the glass substance is not higher than 1350°C, various disadvantages

will arise in case where the viscosity of the glass substance in a formable temperature range, namely, the viscosity in a temperature range not lower than the liquidus temperature is extremely low. Specifically, it is difficult to control the flow rate of glass melt supplied to the forming step in the manufacturing process of the glass substrate. In addition, the degree of freedom in a formable shape is decreased. Therefore, the viscosity of the glass substance for the glass substrate I of this invention is preferably not less than 10 poises, more preferably, not less than 30 poises.

In the meanwhile, when information is recorded in the information recording medium, such as a magnetic disk, an optical disk, and a magnetooptic disk, or when the information is reproduced from the information recording medium, the information recording medium is rotated while it is fixed by a clamp to a spindle of a drive motor arranged in the information processing apparatus. At this time, if a thermal expansion coefficient of the information recording medium is remarkably different from that of the clamp, the following problem will arise.

Specifically, when the information recording medium is rotated, the temperature of each of the information recording medium, the spindle, and the clamp is rapidly increased, for example, up to about 90°C due to heat generation by the drive motor. If the thermal expansion coefficients are much different between the information recording medium and the clamp, this will bring about

loosening between the information recording medium and the clamp and distortion or deflection in the information recording medium when the temperature is increased as described above. As a result, the position of a data recording site (track) in the information recording medium is changed so that an error is liable to occur in information recording and reproducing operations. Particularly, the above-mentioned problem is serious in a large substrate such as a 3.5-inch substrate.

Therefore, it is preferred that the thermal expansion coefficient of the glass substrate I of this invention is approximate to that of the clamp as nearly as possible. Since the above-mentioned clamp is typically made from a stainless alloy, the thermal expansion coefficient (The mean thermal expansion coefficient within a range between 100 and 300°C is meant. The same also applies in the following.) of the glass substrate I of this invention is preferably within a range between 7 and 14 ppm/°C (between 7×10^{-6} and $14 \times 10^{-6}/^{\circ}\text{C}$), more preferably, between 9 and 12 ppm/°C (between 9×10^{-6} and $12 \times 10^{-6}/^{\circ}\text{C}$).

Next, description will be made as regards the glass substrate II of this invention.

As described above, the glass substrate II of this invention comprises a glass substance at least including TiO_2 and CaO as glass components, the contents of TiO_2 and CaO being selected so that the Young's modulus is not smaller than 100GPa and the liquidus temperature is not higher than 1350°C.

The Young's modulus not smaller than 100GPa and the liquidus temperature not higher than 1350°C are selected for the glass substance of the glass substrate II because of the same reason as described in conjunction with the glass substrate I of this invention. The preferable ranges for these physical properties are similar to those described in conjunction with the glass substrate I of this invention.

In order to obtain a glass substance having a high Young's modulus, TiO_2 is preferably included as a glass component. In order to obtain a glass substance having a high Young's modulus and a low liquidus temperature, CaO is preferably included as a glass component.

Therefore, the glass substrate II of this invention is formed by the glass substance at least including TiO_2 and CaO as the glass components. The contents of TiO_2 and CaO are appropriately selected, depending upon the kinds and the contents of the other glass components, so as to obtain the glass substance having the Young's modulus not smaller than 100GPa and the liquidus temperature not higher than 1350°C.

Because of the same reason as described in conjunction with the glass substrate I of this invention, the specific gravity of the glass substrate II is preferably equal to about 3.5g/cm^3 or less, more preferably, equal to about 3.0g/cm^3 or less. Likewise, the thermal expansion coefficient of the glass substrate II preferably falls within a range generally between 7 and 14 ppm/°C

(between 7×10^{-6} and $14 \times 10^{-6}/^{\circ}\text{C}$), more preferably, between 9 and 12 ppm/ $^{\circ}\text{C}$ (between 9×10^{-6} and $12 \times 10^{-6}/^{\circ}\text{C}$).

Next, description will be made as regards the glass substrate III of this invention.

As described above, the glass substrate III of this invention comprises a glass substance at least including TiO_2 and CaO as glass components, the contents of TiO_2 and CaO being selected so that the Young's modulus is not smaller than 100GPa, the liquidus temperature is not higher than 1350°C , and the viscosity in a formable temperature range is not smaller than 10 poises.

The Young's modulus not smaller than 100GPa, the liquidus temperature not higher than 1350°C , and the viscosity in the formable temperature range not smaller than 10 poises are selected for the glass substance forming the glass substrate III because of the same reason as described in conjunction with the glass substrate I of this invention. The preferable ranges for these physical properties are similar to those described in conjunction with the glass substrate I of this invention.

The glass substrate III is formed by the glass substance at least including TiO_2 and CaO because of the same reason as described in conjunction with the glass substrate II of this invention. The contents of TiO_2 and CaO are appropriately selected, depending upon the kinds and the contents of the other glass components, so as to obtain the glass substance having the Young's modulus not smaller than 100GPa, the liquidus temperature not higher

than 1350°C, and the viscosity not smaller than 10 poises in the formable temperature range.

Because of the same reason as described in conjunction with the glass substrate I of this invention, the specific gravity of the glass substrate III is preferably equal to about 3.5g/cm³ or less, more preferably, about 3.0g/cm³ or less. Likewise, the thermal expansion coefficient of the glass substrate III preferably falls within a range generally between 7 and 14 ppm/°C (between 7×10^{-6} and $14 \times 10^{-6}/^{\circ}\text{C}$), more preferably, between 9 and 12 ppm/°C (between 9×10^{-6} and $12 \times 10^{-6}/^{\circ}\text{C}$).

Next, description will be made as regards the glass substrate IV of this invention.

As described above, the glass substrate IV of this invention comprises a glass substance at least including TiO₂, CaO, MgO, Na₂O, Li₂O, and Al₂O₃ as glass components, the contents of the above-mentioned glass components being selected so that the Young's modulus is not smaller than 100 GPa, the liquidus temperature is not higher than 1350°C, the viscosity in a formable temperature range is not smaller than 10 poises, and the specific gravity is not greater than 3.5g/cm³.

The Young's modulus not smaller than 100GPa, the liquidus temperature not higher than 1350°C, the viscosity in the formable temperature range not smaller than 10 poises, and the specific gravity not greater than 3.5g/cm³ are selected for the glass substance forming the glass substrate IV because of the same reason as described in

conjunction with the glass substrate I of this invention. The preferable ranges for these physical properties are similar to those described in conjunction with the glass substrate I of this invention.

As described in conjunction with the glass substrate I of this invention, TiO_2 is a glass component effective in obtaining the glass substance having a high Young's modulus. CaO is a glass component effective in obtaining the glass substance having a high Young's modulus and a low liquidus temperature. It is noted that CaO has a function of increasing the specific gravity.

MgO is also a glass component effective in obtaining the glass substance having a high Young's modulus but has a function of increasing the liquidus temperature as compared with CaO . In addition, MgO has a function of reducing the specific gravity.

Na_2O has a function of decreasing the Young's modulus but contributes to remarkable decrease of the liquidus temperature of the glass substance. Such decrease in liquidus temperature by presence of Na_2O is further remarkable in case where Na_2O and TiO_2 coexist. Na_2O is also a glass component useful in obtaining the glass substance having a high thermal expansion coefficient.

Li_2O is a glass component which is effective in improving the meltability of the glass substance without decreasing the Young's modulus, and which enables augmentation in strength by chemical strengthening.

Al_2O_3 is a glass component which does not contribute to increase or decrease in Young's modulus at all but is effective in decreasing the liquidus temperature of the glass substance, suppressing the phase separation tendency, and improving the viscosity in a working temperature range and the chemical strengthening characteristic.

Therefore, the glass substrate IV of this invention is formed by the glass substance at least including the above-mentioned six kinds of the glass components. The content of each of the above-mentioned glass components is appropriately selected, depending upon the kinds and the contents of the other glass components (including those except the above-mentioned six kinds of the glass components), so as to obtain the glass substance having the Young's modulus not smaller than 100GPa, the liquidus temperature not higher than 1350°C, the viscosity not smaller than 10 poises in the formable temperature range, and the specific gravity not greater than 3.5g/cm³.

Because of the same reason as described in conjunction with the glass substrate I of this invention, the thermal expansion coefficient of the glass substrate IV preferably falls within a range generally between 7 and 14 ppm/°C (between 7×10^{-6} and $14 \times 10^{-6}/^\circ\text{C}$), more preferably, between 9 and 12 ppm/°C (between 9×10^{-6} and $12 \times 10^{-6}/^\circ\text{C}$).

The above-mentioned glass substrate IV has a glass transition point not higher than 650°C, preferably, not higher than 550°C. The glass transition point is a relatively low temperature. Generally, fused salt used in

chemically strengthening the glass substance is held at a temperature 100 to 150°C lower than the glass transition point. On the other hand, the fused salt begins to decompose if the temperature reaches 500°C or more. This results in a damage on the surface of the glass substrate. In order to avoid the situation described above, the above-mentioned glass transition point is preferred.

Next, description will be made as regards the glass substrate V of this invention.

As described above, the glass substrate V of this invention comprises a glass substance including as glass components 0.1-30 mol% of TiO_2 , 1-45 mol% of CaO , 5-40 mol% of $(\text{MgO}+\text{CaO})$, 3-30 mol% of $(\text{Na}_2\text{O}+\text{Li}_2\text{O})$, 0-15 mol% of Al_2O_3 , and 35-65 mol% of SiO_2 .

In the above-mentioned composition, the total amount of $(\text{CaO}+\text{MgO})$ preferably falls within a range between 5 and 35 mol%. In this case, the content of SiO_2 is preferably kept within the range exceeding 55 mol% but up to 65 mol% taking the water durability of the glass substance into consideration. Furthermore, the content of Al_2O_3 may be less than 5 mol%.

The glass substance having the above-mentioned composition easily achieves a Young's modulus not smaller than 100GPa, a liquidus temperature not higher than 1350°C, a viscosity not smaller than 10 poises within a formable temperature range, and a specific gravity not greater than $3.5\text{g}/\text{cm}^3$.

As described above, TiO_2 is a glass component effective in obtaining the glass substance having a high Young's modulus. The content is preferably equal to 0.1 mol% or more in order to obtain the glass substance having a Young's modulus not smaller than 100GPa. However, if the content exceeds 30 mol%, devitrification resistance of the glass substance is decreased. This results in difficulty in obtaining the glass substance having a liquidus temperature not higher than 1350°C.

CaO is a glass component effective in obtaining the glass substance having a high Young's modulus and a low liquidus temperature. The content is preferably equal to 1 mol% or more in order to obtain the glass substance having the Young's modulus not smaller than 100 GPa and the liquidus temperature not higher than 1350°C. However, if the content exceeds 45 mol%, glass formation is difficult.

MgO is a glass component effective in obtaining the glass substance having a high Young's modulus and a low specific gravity. However, MgO has a function of increasing the liquidus temperature of the glass substance. Therefore, the content is preferably selected so that the total amount of MgO and CaO is between 10 and 45 mol%. Desirably, the amount of MgO falls within a range between 5 and 40 mol%. In any event, both of CaO and MgO are contained in the glass substrate according to each of the first through the fifth aspects.

Na_2O is a glass component which has a function of reducing the Young's modulus but significantly decreases

the liquidus temperature of the glass substance. Such a decrease in liquidus temperature by presence of Na_2O is more and more remarkable in case where Na_2O and TiO_2 coexist. Therefore, particularly when the content of TiO_2 is comparatively large (for example, not less than 5 mol%), it is preferred that Na_2O is included. Na_2O is also a glass component useful in obtaining the glass substance having a large thermal expansion coefficient. By appropriately selecting the content, the thermal expansion coefficient of the glass substance can be adjusted. On the other hand, Li_2O is a glass component which is effective in improving the meltability of the glass substance without decreasing the Young's modulus, and which enables augmentation in strength by chemical strengthening. From the above-mentioned reasons, the total amount of Na_2O and Li_2O is preferably equal to 3 mol% or more. However, if the total amount of Na_2O and Li_2O exceeds 30 mol%, chemical durability of the glass substance is deteriorated. In this case, when an information recording medium is obtained by forming a magnetic recording layer on the glass substrate, alkali ions are often diffused from the glass substrate to the recording layer. Preferably, the total amount of Na_2O and Li_2O is between 5 and 22 mol%.

Al_2O_3 is not essential because it is a glass component which does not contribute to increase or decrease in Young's modulus, but may be contained if necessary because it is a glass component effective in decreasing the liquidus temperature of the glass substance, suppressing

the phase separation tendency, and improving the viscosity in a working temperature range and the chemical strengthening characteristic. If Al_2O_3 is contained and the content exceeds 15 mol%, various problems would often arise, such as considerable increase in liquidus temperature and presence of unmelted materials resulting from deterioration in meltability.

SiO_2 is a component forming a glass structure. In order to obtain the glass substance having the liquidus temperature not higher than 1350°C , the content is preferably equal to 35 mol% or more. However, if the content exceeds 65 mol%, it is difficult to obtain the glass substance having the Young's modulus not smaller than 100GPa. More preferably, the content of SiO_2 is between 35 and 65 mol%. SiO_2 is a component having an influence upon dissolution of alkali ions. In view of the water durability, the content between 40 and 60 mol% is effective.

Because of the same reason as described in conjunction with the glass substrate I of this invention, the glass substrate V preferably has the Young's modulus not smaller than 100GPa, the liquidus temperature not higher than 1350°C , the viscosity not smaller than 10 poises in the formable temperature range, the specific gravity not greater than 3.5g/cm^3 , and the thermal expansion coefficient generally between 7 and 14 ppm/ $^\circ\text{C}$ (between 7×10^{-6} and $14 \times 10^{-6}/^\circ\text{C}$). In order to obtain the glass substrate V having desired physical properties, the contents of the glass components are appropriately selected

within the above-mentioned ranges. The preferable ranges for these physical properties are similar to those described in conjunction with the glass substrate I of this invention.

Preferably, the glass substrate V comprises the glass substance including as glass components 5-15 mol% of TiO_2 , 4-20 mol% of CaO , 5-30 mol% of $(\text{MgO}+\text{CaO})$, 5-22 mol% of $(\text{Na}_2\text{O}+\text{Li}_2\text{O})$, 0-8 mol% of Al_2O_3 , and 40-60 mol% of SiO_2 .

In the foregoing, description has been made about the glass substrates I through V of this invention. It is noted here that, in each of the glass substrates comprising the glass substance including TiO_2 as an essential glass component, namely, in each of the glass substrates II, III, IV, and V, a part or a whole of TiO_2 may be replaced by transition metal oxide (except titanium oxide).

Such transition metal oxide is at least one selected from a group consisting of oxides of Cr, Mn, Fe, Co, Ni, Ga, Ge, Y, Zr, Nb, Mo, La, Ce, Pr, Nd, Pn, Ev, Gd, Tb, Dy, Ho, Er, Tn, Yb, Hf, Ta, and W.

Alternatively, use may be made of at least one selected from a group consisting of oxides of Cu, V, and Zn, although the Young's modulus is slightly reduced as compared with the above-mentioned transition metal oxides.

Among the above-enumerated oxides, Y_2O_3 serves to increase the Young's modulus without an increase of the specific gravity. The content of such oxide falls within a range between 0.1 and 15 mol%, preferably, between 0.1 and 8 mol%. Preferably, the transition metal oxide coexists

with TiO_2 of 10 mol% or less. This is because IMPROVEMENT IN YOUNG'S MODULUS/OXIDE CONTENT is slightly decreased if TiO_2 is more than 10 mol%.

It is noted here that the transition metal oxide mentioned above is not so effective in improving the Young's modulus of the glass substance but has a function of increasing the specific gravity. Therefore, the content is suitably selected, depending on the kinds and the contents of the other glass components, so that the desired glass substrate is obtained. If ZrO_2 is used as the transition metal oxide, the content of ZrO_2 is preferably equal to 10 mol% or less, more preferably, 4 mol% or less. When the content of ZrO_2 used as the transition metal oxide is not greater than 5 mol%, the liquidus temperature can be slightly lowered.

Although the glass substrates I through V of this invention can be obtained without chemical strengthening, chemical strengthening may be carried out. If the chemical strengthening (by means of low-temperature ion exchange) is carried out, the glass substance before chemical strengthening preferably includes, as glass components, at least 40 mol% of $(\text{SiO}_2 + \text{Al}_2\text{O}_3)$, at least 3 mol% of Li_2O , at least 5 mol% of $(\text{Na}_2\text{O} + \text{Li}_2\text{O})$, and at most 35 mol% of $(\text{CaO} + \text{MgO})$.

In the above-mentioned case, the content of SiO_2 is preferably equal to 40 mol% or more in order to form a sufficient compressive stress layer by chemical strengthening. It is noted here that a part of SiO_2 can be replaced by Al_2O_3 . Therefore, the total amount of SiO_2 and

Al_2O_3 preferably falls within a range between 40 and 80 mol%. More preferably, the total amount of SiO_2 and Al_2O_3 is equal to 44 mol% or more.

Li_2O and Na_2O serve to introduce into the glass substance Li^+ ions and Na^+ ions required in chemical strengthening. In order to form the sufficient compressive stress layer, it is preferable that the content of Li_2O is not smaller than 3 mol% and the total amount of Na_2O and Li_2O is not smaller than 5 mol%. In order to avoid dissolution of alkali ions from the glass substrate, the total amount of the alkali ions is preferably equal to 22 mol% or less.

On the other hand, CaO and MgO are the glass components effective in adjusting the Young's modulus, the liquidus temperature, and the viscosity in the formable temperature range of the glass substance. However, these components prevent the movement of the alkali ions during chemical strengthening. Therefore, in order to form the sufficient compressive stress layer, it is preferred that the total amount of CaO and MgO is not greater than 35 mol%.

Next, description will be made about the glass substrate VI of this invention.

As described above, the glass substrate VI of this invention is formed by chemically strengthening any one of the glass substrates I through V or by chemically strengthening the glass substance thereof.

Chemical strengthening is an effective measure in obtaining a glass substrate having high impact resistance.

For example, chemical strengthening by the use of low-temperature ion exchange can be performed by dipping the glass substance to be chemically strengthened into a preselected fused salt which comprises carbonate or nitrate of potassium or sodium or a mixture thereof and which is held at a temperature 50-150°C lower than a transition point T_g of the glass substance to be chemically strengthened. On the other hand, the fused salt starts decomposition beyond 500°C to damage the glass substrate. Therefore, it is desired that the glass substrate has a glass transition point not higher than 650°C, preferably, not higher than 550°C.

The glass substrates I through VI of this invention described above are made from amorphous glass which has a high Young's modulus not smaller than 100GPa (glass substrates I through IV and VI) or can easily provide a Young's modulus not smaller than 100GPa (glass substrates V and VI) and which has a liquidus temperature not higher than 1350°C. Therefore, it is easy to obtain from these glass substrates an information recording medium which is adapted to high speed rotation.

The glass substrates I through VI of this invention having the above-mentioned advantages are particularly adapted for use as a substrate for a magnetic disk. In addition, these substrates are also suitable as a substrate for a magnetooptic disk or an optical disk.

Next, description will be made as regards an information recording medium of this invention.

As described above, the information recording medium of this invention comprises any one of the above-mentioned glass substrates I through VI and the recording layer formed on the glass substrate.

It is noted here that, in the information recording medium of this invention, "the recording layer formed on the glass substrate" means a layer which is formed on a surface of the glass substrate directly or via any desired layer and which has a single-layer structure or a multi-layer structure. The material and the layer structure of the recording layer are appropriately selected so as to serve as a magnetic recording layer, a magnetooptic recording layer, an erasable recording layer, or a phase-variable recording layer in correspondence to the type of a desired information recording medium.

The above-mentioned information recording medium essentially comprises as a substrate any one of the above-mentioned glass substrates I through VI. In addition to the substrate and the recording layer, a protection layer and a lubrication layer may appropriately be formed in dependence upon the type of the desired information recording medium, like in the prior art. In dependence upon the type of the information recording medium, the recording layer may be interposed between two substrates. In the information recording medium of such a structure, it is essential to use any one of the glass substrates I through VI of this invention as at least one of the two substrates.

The information recording medium of this invention easily meets the increase in rotation speed since the substrate forming the information recording medium comprises any one of the above-mentioned glass substrates I through VI of this invention. As a result, it is easy to obtain a recording/reproducing apparatus having a high access speed (for example, an auxiliary memory unit used in a personal computer or a server-and-client system) if the information recording medium of this invention is used.

Examples

Now, description will be made as regards specific examples of this invention. Note that the present invention is not restricted by the following examples. For glass substrates obtained in the following examples, the thickness of the compressive stress layer and the physical properties of the glass substrates were obtained in the following manner.

1. Thickness of Compressive Stress Layer

Measurement was made by the use of the precision strainmeter (Babinet compensation) manufactured by Toshiba Glass K.K.

2. Physical Properties

(1) Young's Modulus

Each sample having a dimension of 20 x 20 x 100 mm was prepared. An ultrasonic wave of 5MHz is made to propagate through the sample to measure a velocity of longitudinal wave (V_l) and a velocity of transversal wave

(V_s) by the use of the sing-around sound velocity measuring equipment (UVM-2 manufactured by Ultrasonic Engineering Co., Ltd.). Then, calculation was made by the following equation.

$$\text{Young's modulus} = (4G^2 - 3G \cdot V_1^2 \cdot \rho) / (G - V_1^2 \cdot \rho)$$

$$G = V_s^2 \cdot \rho$$

ρ : Specific Gravity (g/cm^3) of Sample.

(2) Specific Modulus

Calculation was made by dividing the Young's modulus of the sample by its specific gravity.

(3) Liquidus Temperature

The sample was put into a platinum container and was held in a temperature gradient furnace for thirty minutes. Thereafter, the surface and the interior of the sample were observed by an optical microscope for presence or absence of crystals. The liquidus temperature was defined as a lowest temperature at which no crystal was precipitated.

(4) Viscosity

Measurement was made over a range from the melting temperature to the liquidus temperature by the use of the rotary viscometer comprising a platinum container and a platinum rotor.

(5) Glass Transition Point (T_g)

For the sample having a dimension of $5\text{mm}\phi \times 20\text{mm}$, measurement was made by the use of the thermomechanical analyzer (TMA8140) manufactured by Rigaku Corp. at a heating rate of $+4^\circ\text{C}/\text{min}$. As a reference sample, SiO_2 was used.

(6) Thermal Expansion Coefficient

A mean coefficient of thermal expansion between 100°C and 300°C is meant. Measurement was performed simultaneously when the glass transition point was measured.

(7) Surface Roughness (Ra)

Measurement was made by the use of the AFM NanoScope 3A manufactured by Digital Instrument Corp.

Examples 1-30

In order to obtain glass substances having oxide compositions shown in Tables 1 through 5, glass materials, such as silicate powder, aluminum hydroxide, alumina, lithium carbonate, lithium sulfate, sodium carbonate, sodium nitrate, calcium carbonate, magnesium carbonate, magnesium oxide, titanium oxide, iron oxide, nickel oxide, yttrium oxide, lanthan oxide, neodymium oxide, copper oxide, antimony oxide, and arsenious acid were appropriately weighted or measured to prepare a mixture of 100kg for each example.

Next, melted glass was prepared in the following manner by the use of an atmosphere-heating type semicontinuous melting equipment of platinum which comprises a melting furnace having an internal volume of 2 liters, a working tank connected to the melting furnace and having an internal volume of 30 liters with a stirrer, and a cylindrical outflow tube having an inner diameter between 5mm and 20mm and connected to the working tank. Specifically, the above-mentioned mixture was put in the melting furnace to be melted at a temperature between

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1350°C and 1450°C and then stirred in the working tank to be clarified or refined. Thus, melted glass was obtained.

The melted glass thus obtained was made to flow out from the cylindrical outflow tube at a temperature slightly higher than the liquidus temperature to be received in a molding die (lower die) having a circular shape (diameter of 100mm) and made from cast iron. The melted glass was quickly pressed by an upper die made from cast iron and then annealed to obtain a disk-shaped object having a diameter of about 100mm and a thickness of 1mm. With the composition of this invention, the liquidus temperature is not higher than 1350°C and the surface tension is high. Therefore, pressing was performed without any deformation due to spreading at the periphery. A glass substrate after pressing was excellent in reproducibility for the molding die and presence of bubbles at the periphery was not observed.

Thereafter, the above-mentioned disk-shaped object was subjected to a grinding process and a polishing process (using a cerium oxide polisher) to obtain a disk-shaped glass substrate having a dimension of 3.5 inches ϕ x 0.635mm.

In each example excluding Examples 25 and 26, chemical strengthening was performed in the following manner to obtain a desired glass substrate.

At first, a salt mixture of NaNO_3 and KNO_3 at a weight ratio of 6 : 4 was prepared. The salt mixture was heated to a temperature 100°C lower than the glass

transition point (T_g) of the glass substrate to be chemically strengthened and was melted to obtain fused salt. Then, the glass substrate to be chemically strengthened was dipped into the fused salt for nine hours. Thus, chemical strengthening was performed.

The thickness of the compressive stress layer in each glass substrate (excluding the glass substrates in Examples 25 and 26) thus obtained and the physical property of each glass substrate are shown in Tables 1 through 5. All of the Young's modulus, the specific modulus, the surface roughness (R_a), and the specific gravity were measured by the use of the glass samples after chemically strengthened (except for the glass substrates of Examples 25 and 26). On the other hand, the liquidus temperature, the viscosity, the glass transition point, and the thermal expansion coefficient were measured by the use of the glass samples which were not chemically strengthened.

Comparative Example 1

Glass materials were weighted so as to obtain a glass substance having a composition (in terms of mol%) substantially same as that described in Example 1 of Japanese Unexamined Patent Publication (JP-A) No. 1-167245. In the manner similar to Examples 1 through 30 described above, a glass substrate (before chemically strengthened) was obtained and thereafter chemically strengthened under the same condition as in Examples 1 through 30 to obtain a desired glass substrate.

For the glass substrate, the thickness of the compressive stress layer, the Young's modulus, the specific gravity, the specific modulus, and the glass transition point were obtained in the manner similar to Examples 1 through 30. These values are shown in Table 6.

Comparative Example 2

Glass materials were weighted so as to obtain a glass substance having a composition (in terms of mol %) substantially same as that described in Example 1 of Japanese Patent Publication (JP-B) No. 6-76224. In the manner similar to Examples 1 through 30 described above, a glass substrate (before chemically strengthened) was obtained and thereafter chemically strengthened under the same condition as in Examples 1 through 30 to obtain a desired glass substrate.

For the glass substrate, the thickness of the compressive stress layer, the Young's modulus, the specific gravity, the specific modulus, and the liquidus temperature were obtained in the manner similar to Examples 1 through 30. These values are shown in Table 6.

Comparative Example 3

Glass materials were weighted so as to obtain a glass substance having a composition (in terms of mol%) substantially same as that described in Example 1 (Glass of Composition 2) of Japanese Patent Publication (JP-B) No. 4-70262. In the manner similar to Examples 1 through 30 described above, a glass substrate (before chemically strengthened) was obtained and thereafter chemically

strengthened under the same condition as in Examples 1 through 30 to obtain a desired glass substrate.

For the glass substrate, the thickness of the compressive stress layer, the Young's modulus, the specific gravity, the specific modulus, the thermal expansion coefficient, and the glass transition point were obtained in the manner similar to Examples 1 through 30. These values are shown in Table 6.

Comparative Example 4

Glass materials were weighted so as to obtain a glass substance having a composition (in terms of mol%) substantially same as that described in the claim of Japanese Unexamined Patent Publication (JP-A) No. 7-187711. A melt was obtained and subjected to heat treatment at the temperature and for the time period specified in the above-mentioned claim to obtain a crystallized glass. Thereafter, the crystallized glass was processed in the manner similar to Examples 1 through 30 to obtain a desired glass substrate.

For the glass substrate, the Young's modulus, the specific gravity, the specific modulus, and the surface roughness were obtained in the manner similar to Examples 1 through 30. These values are shown in Table 6.

As seen from Tables 1 through 5, each of the glass substrates obtained in Examples 1 through 30 has a high Young's modulus between 102 and 120 GPa and an excellent surface roughness (Ra) between 3 and 5 angstroms. The

liquidus temperature of the glass substance as a material for each of these glass substrates is relatively low, specifically, between 1000 and 1230°C. Therefore, it is supposed that, if a magnetic disk is prepared by the use of any one of these glass substrates, a flying height can be stably kept at about 1 μ m or less even during the high speed rotation.

On the other hand, each of the glass substrates obtained in Comparative Examples 1 through 3 has a low Young's modulus between 74 and 78 GPa. The crystallized glass substrate obtained in Comparative Example 4 has a surface roughness (Ra) as inferior as 25 angstroms. Therefore, it is supposed that, if a magnetic disk is prepared by the use of any one of these glass substrates and the crystallized glass substrate, a stable flying height of about 1 μ m or less is difficult to keep during the high speed rotation.

As is obvious from Tables 1 through 5, it is understood that each of Examples 1 through 30 has a composition range specified by 35-65 mol% of SiO₂, 0-15 mol% of Al₂O₃, 3-30 mol% of (Li₂O+Na₂O), 1-45 mol% of CaO, 5-45 mol% of (MgO+CaO), and 0.1-30 mol% of TiO₂. Especially, it has been found out that the amount of (MgO+CaO) is preferably within a range between 5 and 35 mol% and that the amount of SiO₂ preferably falls within a range which exceeds 55 mol% and which does not exceed 65 mol%.

Examples 31 through 36

A magnetic disk was prepared in the following manner by the use of the glass substrate obtained in each of Examples 25 through 30.

At first, a texture was formed on a landing zone of each glass substrate by the use of a laser beam so as to prevent attraction between the magnetic head and the magnetic disk.

Subsequently, a Cr underlying layer, a CoPtCrTa magnetic layer, and a carbon protection layer were successively formed on a surface of the glass substrate which is provided with the texture. Thus, the magnetic disk was obtained.

Each magnetic disk thus prepared was mounted on a hard disk unit and rotated at 12000 rpm with the flying height kept at 1 μ m or less to be subjected to a recording/reproducing test by an MR head. As a result, in all of the magnetic disks, recording/reproducing operations could be normally carried out.

Next, description will be directed to the substrate for an information recording medium according to the second embodiment of this invention. The substrate for an information recording medium according to the second embodiment of this invention is based on each of the seventh through the ninth aspects of this invention. The glass substrate according to the seventh aspect, i.e., the substrate for an information recording medium includes coexistence of Y_2O_3 and TiO_2 to obtain the Young's modulus

and the liquidus temperature mentioned above. This substrate will be referred to as a glass substrate I of the second embodiment. More specifically, the glass substrate I of the second embodiment includes Y_2O_3 and TiO_2 in addition to SiO_2 , Al_2O_3 , MgO and/or CaO , and Li_2O .

A glass substrate II according to the eighth aspect of this invention includes Y_2O_3 , TiO_2 , and ZrO_2 in addition to SiO_2 , Al_2O_3 , MgO and/or CaO , and Li_2O .

Moreover, a glass substrate III according to the ninth aspect of this invention includes TiO_2 and at least one oxide which is selected from a rare earth metal oxide group consisting of Er_2O_3 , Nd_2O_3 , Sm_2O_3 , Eu_2O_3 , Gd_2O_3 , Tb_2O_3 , Dy_2O_3 , and Yb_2O_3 . It has been found out that the glass substrate having a desired Young's modulus and a desired liquidus temperature can also be obtained by inclusion of only TiO_2 and ZrO_2 in a composition of SiO_2 , Al_2O_3 , MgO and/or CaO , and Li_2O . Herein, the glass substrate is called a glass substrate IV according to the second embodiment. The rare earth metal oxide mentioned above also serves to increase the Young's modulus like the transition metal oxide but is liable to increase the specific gravity. Taking this into consideration, it is effective that such rare earth metal oxide is contained in the amount between 0 and 10 mol%.

Table 7 shows Examples 1 through 48 for the above-mentioned glass substrates I, II, III, and IV. Among Examples 1 through 48 shown in Table 7, each of Examples 1, 2, 3, 4, 5, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21,

22, 24, 25, 29, 36, 37, and 38 includes Y_2O_3 , TiO_2 , and ZrO_2 and corresponds to the glass substrate II of the second embodiment. On the other hand, each of Examples 6, 7, 8, 20, 23, 26, 27, 28, 30, 31, 32, 33, 34, 35, 39, and 40 includes Y_2O_3 and TiO_2 and corresponds to the glass substrate I of the second embodiment. Each of Examples 41 through 48 includes TiO_2 and rare earth metal oxide and corresponds to the glass substrate III of the second embodiment.

Next, reference will be made to Table 8. Table 8 shows Examples 49 to 63. These Examples are classified into the glass substrates I, II, III, and IV of the second embodiment. Specifically, each of Examples 49, 52, 53, 55, 58, 62, and 63 includes coexistence of TiO_2 and Y_2O_3 and thus is the glass substrate I of the second embodiment. On the other hand, each of Examples 50, 54, 55, 56, 57, and 59 includes TiO_2 , Y_2O_3 , and ZrO_2 and corresponds to the glass substrate II of the second embodiment. Each of Examples 61 and 62 including TiO_2 and ZrO_2 alone corresponds to the glass substrate IV of the second embodiment.

Table 8 shows the thickness of the compressive stress layer, the viscosity, the specific gravity, the liquidus temperature, the specific modulus, the Young's modulus, the glass transition point (T_g), the thermal expansion coefficient, and the surface roughness for each of Examples.

As is obvious from Tables 7 and 8, each of Examples 48 through 63 of the second embodiment comprises 45-65 mol% of SiO_2 , 0-15 mol% of Al_2O_3 , 4-20 mol% of Li_2O , 1-8 mol% of

Na_2O , 3-30 mol% of $(\text{Li}_2\text{O}+\text{Na}_2\text{O})$, 0-21 mol% of CaO , 0-22 mol% of MgO , 4-40 mol% of $(\text{CaO}+\text{MgO})$, 0-16 mol% of Y_2O_3 , 1-15 mol% of TiO_2 , and 0-10 mol% of ZrO_2 . Each of Examples 41 to 48 which do not contain Y_2O_3 comprises 5 mol% of at least one oxide selected from a rare earth metal oxide group consisting of Er_2O_3 , Nd_2O_3 , Sm_2O_3 , Eu_2O_3 , Gd_2O_3 , Tb_2O_3 , Dy_2O_3 , and Yb_2O_3 .

Furthermore, each of the glass substrates according to the first and the second embodiments was immersed in water in order to measure the amount of dissolution of alkali ions. Table 9 shows the amounts of dissolution per 2.5-inch disk and per unit area for each of Examples 2, 4, 29, 9, 3, and 17 of the first embodiment and Examples 49 and 50 of the second embodiment. As is obvious from Table 9, Examples 9, 13, and 17 are smaller in amount of dissolution than in Examples 2, 4, and 29. The same also applies to Examples 49 and 50. This means that the amount of dissolution tends to decrease with an increase of the amount of SiO_2 .

As seen from Tables 7 and 8, each of Examples 1 through 63 of the second embodiment has the Young's modulus not smaller than 100GPa and the liquidus temperature not higher than 1350 °C.

Furthermore, each of Examples 16, 17, 20, 23, and 31 of the second embodiment was chemically strengthened in a predetermined treating bath at a preselected ion exchange temperature. For each glass substrate chemically strengthened, measurement was made of the Young's modulus,

the glass transition point (T_g), the surface roughness, and the bending strength. The results are tabulated in Table 10.

Finally referring to Fig. 1, description will be made about the correlation between the Young's modulus and the vibration of the information recording medium, i.e., the disk. Herein, illustration is made about the disks using the conventional substrates and the disks using the information recording substrates of this invention. More specifically, the disk A comprises an aluminum substrate. The disk B comprises an SiO_2 substrate. The disks C and D comprise the substrates in Comparative Examples 1 and 2 mentioned above, respectively. Each of these disks A, B, C, and D has the Young's modulus not greater than 80 GPa.

On the other hand, those substrates in Examples 8, 10, 15, 24, and 30 shown in Tables 2 through 5 were used as the information recording substrates of this invention. By the use of these substrates, the disks E8, 10, 15, 24, and 30 were formed.

Each of the above-mentioned substrates had a diameter of 3.5 inches and was rotated at a speed of 10,000 rpm. Then, a relative value of vibration was measured. In the figure, the vibration of the disk A among the conventional disks is represented as 100 while the vibration of other disks is given as the relative values. As illustrated in the figure, the vibration of each of the disks E8, 10, 15, 24, and 30 in Examples of this invention having the Young's modulus not smaller than 100 GPa (Examples 8, 10, 15, 24,

and 30 in Tables 2 through 5) can be reduced to 60% or less as compared with the typical conventional disk formed by the aluminum substrate (A), as illustrated in Fig. 1. It will be understood that each of the disks B, C, and D comprising the other conventional substrates exhibits the vibration on the order or 90% with respect to the vibration of the disk A as 100. Thus, the substrate for an information recording medium according to this invention has a high Young's modulus and, when the disk is formed therefrom, can suppress the vibration so that the flying height can be stabilized.

Industrial Applicability

As described above, with the substrate (glass substrate) of this invention, it is possible to obtain the information recording medium which can readily meet the increase in rotation speed. Thus, the recording/reproducing apparatus having a high recording capacity and a high access speed can be obtained by the use of the information recording medium comprising the substrate according to this invention.

Table 1

	Example 1	Example 2	Example 3	Example 4	Example 5	Example 6
Glass Composition (mol%)	SiO ₂	42	46	35	42	40
	Al ₂ O ₃	8	-	8	6	10
	Li ₂ O	6	5	4	4	2
	Na ₂ O	-	5	6	8	7
	Li ₂ O+Na ₂ O	6	10	10	12	9
	CaO	15	13	20	8	12
	MgO	15	10	12	2	12
	CaO+MgO	30	23	30	10	24
	TiO ₂	6	23	15	30	15
Thickness of Compressive Stress Layer (μ m)	Other Components	-	-	Fe ₂ O ₃ : 2	-	Y ₂ O ₃ : 2
		40	55	75	20	65
	Young's Modulus (GPa)	104	113	110	104	103
	Specific Gravity (g/cm ³)	2.75	3.10	2.90	2.96	2.91
	Specific Modulus (x10 ⁶ Nm/kg)	37.8	36.5	37.9	35.2	35.4
	Liquidus Temperature (°C)	1120	1180	1150	1180	1180
	Viscosity at 1200°C	10 poises	20 poises	30 poises	20 poises	40 poises
	Viscosity at 1100°C	50 poises	-	-	-	-
	Viscosity at 1250°C	-	-	-	-	-
Physical Properties	Thermal Expansion Coefficient (ppm/°C)	7.0	8.6	9.1	9.3	8.4
	Glass Transition Point (T _g , °C)	620	616	575	610	645
	Surface Roughness (Ra)	3 angstroms	3 angstroms	4 angstroms	4 angstroms	4 angstroms

	Example 7	Example 8	Example 9	Example 10	Example 11	Example 12
Glass Composition (mol%)	SiO ₂	40	48	60	42	50
	Al ₂ O ₃	2	-	-	-	3
	Li ₂ O	6	18	6	12	10
	Na ₂ O	2	-	3	18	5
	Li ₂ O+Na ₂ O	8	18	9	30	15
	CaO	15	20	9	1	8
	MgO	30	-	9	13	10
	CaO+MgO	45	20	18	14	18
	TiO ₂	5	7	11	14	12
	Other Components		ZrO ₂ : 4 Nb ₂ O ₃ : 2 La ₂ O ₃ : 1	ZrO ₂ : 2		NiO: 2
Thickness of Compressive Stress Layer (μ m)						
Physical Properties	Young's Modulus (GPa)	20	40	70	40	80
	Specific Gravity (g/cm ³)	115	110	102	102	104
	Specific Modulus (x10 ⁶ Nm/kg)	2.88	3.00	2.79	2.76	2.77
	Liquidus Temperature (°C)	40.0	36.7	36.6	37.0	37.6
	Viscosity at 1200°C	1150	1000	1080	1190	1150
	Viscosity at 1100°C	20 poises	5 poises	40 poises	20 poises	10 poises
	Viscosity at 1250°C	-	15 poises	80 poises	-	-
	Thermal Expansion Coefficient (ppm/°C)	-	-	-	-	-
	Glass Transition Point (Tg:°C)	9.0	9.5	7.3	13.7	9.2
	Surface Roughness (Ra)	570	535	605	420	537
	4 angstroms	3 angstroms	3 angstroms	4 angstroms	3 angstroms	3 angstroms

Table 3

	Example 13	Example 14	Example 15	Example 16	Example 17	Example 18
SiO ₂	54	44	45	42	46	44
Al ₂ O ₃	-	2	2	-	-	-
Li ₂ O	12	9	10	4	4	4
Na ₂ O	8	4	3	5	6	5
Li ₂ O+Na ₂ O	20	13	13	9	10	9
CaO	2	14	13	15	15	14
MgO	8	14	13	15	13	14
CaO+MgO	10	28	26	30	28	28
TiO ₂	16	13	14	15	12	15
Other Components				Nb ₂ O ₅ : 2 La ₂ O ₃ : 2	Nd ₂ O ₃ : 2 ZrO ₂ : 2	CuO: 2 ZrO ₂ : 2
Thickness of Compressive Stress Layer (μ m)	40	65	40	25	40	30
Young's Modulus (GPa)	102	109	111	112	102	110
Specific Gravity (g/cm ³)	2.73	2.87	2.86	3.22	2.73	3.00
Specific Modulus ($\times 10^6$ Nm/kg)	37.4	38.0	38.9	34.9	37.4	36.7
Liquidus Temperature (°C)	1200	1020	1080	1150	1200	1180
Viscosity at 1200°C	20 poises	10 poises	30 poises	20 poises	15 poises	30 poises
Viscosity at 1100°C	-	30 poises	-	-	-	-
Viscosity at 1250°C	-	-	-	-	-	-
Thermal Expansion Coefficient (ppm/°C)	9.8	8.4	8.4	9.1	9.8	8.9
Glass Transition Point (T _g :°C)	505	650	645	600	505	605
Surface Roughness (Ra)	3 angstroms	4 angstroms	3 angstroms	4 angstroms	4 angstroms	3 angstroms

Table 4

	Example 19	Example 20	Example 21	Example 22	Example 23	Example 24
Glass Composition (mol%)	SiO ₂	40	45	45	44	45
	Al ₂ O ₃	-	2	2	2	1
	Li ₂ O	4	10	10	10	12
	Na ₂ O	-	3	2	4	5
	Li ₂ O+Na ₂ O	4	13	12	14	17
	CaO	36	11	10	14	13
	MgO	-	15	15	15	13
	CaO+MgO	36	26	25	29	26
	TiO ₂	8	14	14	11	11
	Other Components	La ₂ O ₃ : 1 ZrO ₂ : 5 Nb ₂ O ₅ : 6		ZrO ₂ : 2		
Thickness of Compressive Stress Layer (μ m)						
Physical Properties	Young's Modulus (GPa)	115	110	111	109	108
	Specific Gravity (g/cm ³)	3.51	2.86	2.92	2.86	2.83
	Specific Modulus ($\times 10^6$ Nm/kg)	32.8	38.5	38.1	38.1	38.1
	Liquidus Temperature ($^{\circ}$ C)	1200	1100	1100	1070	1080
	Viscosity at 1200 $^{\circ}$ C	20 poises	10 poises	20 poises	10 poises	10 poises
	Viscosity at 1100 $^{\circ}$ C	-	30 poises	40 poises	20 poises	20 poises
	Viscosity at 1250 $^{\circ}$ C	-	-	-	-	-
	Thermal Expansion Coefficient (ppm/ $^{\circ}$ C)	8.9	9.3	9.4	10.1	10.7
Glass Transition Point (T _g : $^{\circ}$ C)						
		670	560	565	540	530
Surface Roughness (Ra)						
		4 angstroms	3 angstroms	3 angstroms	4 angstroms	3 angstroms
						4 angstroms

Table 5

	Example 25	Example 26	Example 27	Example 28	Example 29	Example 30
Glass Composition (mol%)	SiO ₂	46	46	45	37	38
	Al ₂ O ₃	-	-	4	2	2
	Li ₂ O	5	8	10	4	9
	Na ₂ O	-	-	3	2	2
	Li ₂ O+Na ₂ O	5	8	13	6	11
	CaO	33	7	9	19	14
	MgO	-	-	17	24	15
	CaO+MgO	33	7	26	44	29
	TiO ₂	10	7	13	14	16
	Other Components	La ₂ O ₃ : 1 ZrO ₂ : 6 Nb ₂ O ₃ : 6	La ₂ O ₃ : 7 ZrO ₂ : 2 ZnO: 23			ZrO ₂ : 4
Thickness of Compressive Stress Layer (μ m)						
Physical Properties	Young's Modulus (GPa)	116	108	110	118	120
	Specific Gravity (g/cm ³)	3.53	3.93	2.88	3.05	3.05
	Specific Modulus ($\times 10^6$ Nm/kg)	32.9	27.5	38.1	38.8	39.5
	Liquidus Temperature (°C)	1220	1230	1100	1230	1230
	Viscosity at 1200°C	<10 poises	-	20 poises	-	-
	Viscosity at 1100°C	-	-	-	-	-
	Viscosity at 1250°C	-	<10 poises	-	10 poises	20 poises
	Thermal Expansion Coefficient (ppm/°C)	8.9	7.9	9.4	8.8	9.1
Glass Transition Point (Tg:°C)						
		660	580	560	537	595
Surface Roughness (Ra)						
	4 angstroms	4 angstroms	3 angstroms	3 angstroms	5 angstroms	4 angstroms

Table 6

	Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4
SiO ₂	64.2	68.5	67.2	52.0
Al ₂ O ₃	7.6	8.8	1.8	1.0
Li ₂ O	-	10.0	-	-
Na ₂ O	14.5	8.2	9.4	7.0
K ₂ O	2.0	-	6.2	5.0
CaO	-	-	0.1	16.0
MgO	6.4	4.5	4.5	-
BaO	0.2	-	-	-
TiO ₂	4.0	-	0.5	-
ZrO ₂	1.0	-	-	-
ZnO	-	-	9.1	-
B ₂ O ₃	-	-	1.0	-
As ₂ O ₃	-	-	0.07	-
Sb ₂ O ₃	-	-	0.07	-
F	-	-	-	19.0
Thickness of Compressive Stress Layer (μ m)	75	270	85	-
Young's Modulus (GPa)	74	78	76	93
Specific Gravity (g/cm ³)	2.56	2.43	2.41	2.60
Specific Modulus (x10 ⁶ Nm/kg)	29.1	31.9	31.3	35.0
Liquidus Temperature (°C)	-	960	-	-
Thermal Expansion Coefficient (ppm/°C)	-	-	9.6	-
Glass Transition Point (Tg:°C)	626	-	555	-
Surface Roughness (Rmax)	-	-	-	25 angstroms

Glass
Composi-
tion
(mol%)Physical
Properties

Table 7-1 GLASS COMPOSITIONS OF EXAMPLES AND COMPARATIVE EXAMPLES (mol%)

[illegible]

Table 7-2 GLASS COMPOSITIONS OF EXAMPLES AND COMPARATIVE EXAMPLES (mol%)

[illegible]

[illegible]

Table 7-4 GLASS COMPOSITIONS OF EXAMPLES AND COMPARATIVE EXAMPLES (mol%)

	Example							
	42	43	44	45	46	47	48	
SiO2	52.0	52.0	52.0	52.0	52.0	52.0	52.0	
Al2O3	5.0	5.0	5.0	5.0	5.0	5.0	5.0	
MgO	10.5	10.5	10.5	10.5	10.5	10.5	10.5	
CaO	10.5	10.5	10.5	10.5	10.5	10.5	10.5	
Li2O	10.0	10.0	10.0	10.0	10.0	10.0	10.0	
Nd2O3	5.0							
Sm2O3		5.0						
Eu2O3			5.0					
Gd2O3				5.0				
Tb2O3					5.0			
Dy2O3						5.0		
Yb2O3							5.0	
TiO2	7.0	7.0	7.0	7.0	7.0	7.0	7.0	
Na2O								
Y2O3								
ZrO2								
Liquidus Temperature (°C)	1124	1121	1132	1119	1234	1211	1195	
Young's Modulus (Gpa)	106.6	106.9	107.3	107.8	108.1	108.5	109.9	
Tg (°C)	611	608	610	606	605	610	612	
Surface Roughness (Å)	3	3	3	3	3	3	3	

Table 8-1

	Example 49	Example 50	Example 51	Example 52	Example 53	Example 54
SiO ₂	52	58	55	45	55	45
Al ₂ O ₃	6	3	7	10	9	4
Li ₂ O	10	12	10	9	19	20
Na ₂ O	-	4	-	-	-	8
Li ₂ O+Na ₂ O	10	16	10	9	19	28
CaO	11	6	4	5	5	1
MgO	11	6	14	15	3	4
CaO+MgO	22	12	18	20	8	5
TiO ₂	7	8	5.5	15	3	12
Y ₂ O ₃	3	0.5	2	1	6	1
ZrO ₂	-	2.5	2.5	-	-	5
Other Components						
Thickness of Compressive Stress Layer (μ m)	50	80	75	30	85	90
Young's Modulus (GPa)	110	102	107	107	104	106
Specific Gravity (g/cm ³)	2.87	2.73	2.79	2.82	2.71	2.83
Specific Modulus ($\times 10^6$ Nm/kg)	38	37	38	38	38	37
Liquidus Temperature ($^{\circ}$ C)	1150	1100	1240	1110	1020	990
Viscosity at 1200 $^{\circ}$ C	50	40	-	30	50	10
Viscosity at 1100 $^{\circ}$ C	-	-	-	-	110	30
Viscosity at 1250 $^{\circ}$ C	-	-	20	-	-	-
Thermal Expansion Coefficient (ppm/ $^{\circ}$ C)	7.9	8.0	6.9	7.0	8.6	11.5
Glass Transition Point (Tg: $^{\circ}$ C)	569	554	615	620	465	400
Surface Roughness (Ra)	4	3	3	4	5	4

Table 8-2

	Example 55	Example 56	Example 57	Example 58	Example 59	Example 60	Example 61	Example 62	Example 63
Glass Composition (mol%)	SiO ₂	40	65	60	45	58	45	58	52
	Al ₂ O ₃	3	5	2	2	4	2	6	6.5
	Li ₂ O	7	4	16	10	5	12	12	10
	Na ₂ O	-	-	5	7	1	3	-	-
	Li ₂ O+Na ₂ O	7	4	21	17	6	15	12	10
	CaO	18	7	4	15	3	12	8	12
	MgO	22	7	4	10	16	12	6	8
	CaO+MgO	40	14	8	25	19	24	14	20
	TiO ₂	4	1	5	10	8	12	8	7
	Y ₂ O ₃	5	6	3	1	0.8	-	2	2.5
Physical Properties	ZrO ₂	1	5	1	-	4.2	2	-	2
	Other Components								
	Thickness of Compressive Stress Layer (μ m)	40	20	80	40	35	70	65	50
	Young's Modulus (GPa)	115	101	100	108	103	112	104	110
	Specific Gravity (g/cm ³)	3.12	2.88	2.67	2.83	2.79	2.85	2.74	2.89
	Specific Modulus ($\times 10^6$ Nm/kg)	37	35	37	38	37	39	38	38
	Liquidus Temperature (°C)	1210	1110	990	1120	1090	1130	1060	1220
	Viscosity at 1200°C	20	100	30	20	40	20	50	-
	Viscosity at 1100°C	40	-	70	-	80	-	100	-
	Viscosity at 1250°C	-	-	-	-	-	-	10	<10
Thermal Properties	Thermal Expansion Coefficient (ppm/°C)	8.9	7.2	9.6	9.6	7.8	9.3	7.7	7.8
	Glass Transition Point (T _g °C)	570	620	455	565	610	565	525	610
	Surface Roughness (Ra)	6	5	5	3	3	4	5	3

Table 9

Example	2	4	29	9	13	17	49	50
SiO ₂	42	35	37	60	54	46	52	58
Al ₂ O ₃	2	8	2	0	0	0	6	3
Li ₂ O	5	4	4	6	12	4	10	12
Na ₂ O	5	6	2	3	8	5		4
CaO	13	18	19	9	2	15	11	6
MgO	10	12	24	9	8	15	11	6
TiO ₂	23	15	14	11	16	15	7	8
Fe ₂ O ₃		2						
ZrO ₂				2				2.5
Nb ₂ O ₃						2		
La ₂ O ₃						2		
Y ₂ O ₃							3	0.5
Dissolution of Alkali Ion (μ mol/disk)	43.3	75	82	5.1	9.5	18	6	2.7
Dissolution of Alkali Ion (μ mol/cm ²)	0.72	1.25	1.37	0.09	0.16	0.3	0.1	0.045

Table 10 EXAMPLES AND COMPARATIVE EXAMPLES OF CHEMICALLY STRENGTHENED GLASS

	Example					
	16	17	20	23	31	
SiO ₂	52.0	52.0	52.0	52.0	52.0	
Al ₂ O ₃	8.0	5.5	6.0	5.5	5.0	
MgO	8.0	7.0	11.0	7.0	10.0	
CaO	14.0	14.0	11.0	15.0	10.0	
Li ₂ O	10.0	10.0	10.0	10.0	12.5	
Y ₂ O ₃	2.0	2.5	3.0	3.5	3.0	
TiO ₂	6.0	7.0	7.0	7.0	7.5	
ZrO ₂	2.0	2.0				
Transition Point (°C)	607	607	598	603	580	
Young's Modulus (Gpa)	109.8	110.2	110.0	110.3	110.5	
Surface Roughness (Å)	3	3	3	3	3	
Bending Strength (kg/mm ²)	75.0	72.0	81.0	79.0	86.0	
Treatment Bath	60%KNO ₃ +40%NaNO ₃	60%KNO ₃ +40%NaNO ₃	KNO ₃	NaNO ₃	60%KNO ₃ +40%NaNO ₃	
Ion Exchange Temperature (°C)	500	500	490	500	480	
Processing Time (h)	4.0	4.0	4.0	4.0	4.0	

CLAIMS

1. A substrate for an information recording medium, comprising a glass substance having a Young's modulus not smaller than 100GPa and a liquidus temperature not higher than 1350°C.

2. A substrate as claimed in claim 1, having a specific gravity not greater than 3.5g/cm³.

3. A substrate as claimed in claim 1 or 2, wherein said glass substance has a viscosity not smaller than 10 poises in a formable temperature range.

4. A substrate as claimed in any one of claims 1 through 3, having a thermal expansion coefficient between 7 and 14ppm/°C.

5. A substrate for an information recording medium, comprising a glass substance at least including TiO₂ and CaO as glass components, the contents of TiO₂ and CaO being selected so that a Young's modulus is not smaller than 100GPa and a liquidus temperature is not higher than 1350°C.

6. A substrate for an information recording medium, comprising a glass substance at least including TiO₂ and CaO as glass components, the contents of TiO₂ and CaO being selected so that a Young's modulus is not smaller than 100GPa, a liquidus temperature is not higher than 1350°C, and a viscosity is not smaller than 10 poises in a formable temperature range.

7. A substrate for an information recording medium, comprising a glass substance which includes, as glass components, TiO_2 , CaO , MgO , and Al_2O_3 along with at least Li_2O selected from a group of Na_2O and Li_2O , the contents of these glass components being selected so that a Young's modulus is not smaller than 100GPa, a liquidus temperature is not higher than 1350°C , a viscosity in a formable temperature range is not smaller than 10 poises, and a specific gravity is not greater than 3.5g/cm^3 .

8. A substrate for an information recording medium as claimed in claim 7, further including Y_2O_3 and ZrO_2 .

9. A substrate for an information recording medium as claimed in claim 7 or 8, wherein a glass transition point is not higher than 650°C .

10. A substrate for an information recording medium as claimed in claim 9, wherein a glass transition point is not higher than 550°C .

11. A substrate for an information recording medium, comprising a glass substance including, as glass components, 0.1-30 mol% of TiO_2 , 1-45 mol% of CaO , 5-40 mol% of $(\text{MgO}+\text{CaO})$, 3-30 mol% of $(\text{Na}_2\text{O}+\text{Li}_2\text{O})$, less than 15 mol% of Al_2O_3 , and 35-65 mol% of SiO_2 .

12. A substrate for an information recording medium, comprising a glass substance including, as glass components, 0.1-30 mol% of TiO_2 , 1-45 mol% of CaO , 5-40 mol% of $(\text{MgO}+\text{CaO})$, 3-30 mol% of $(\text{Na}_2\text{O}+\text{Li}_2\text{O})$, 0-less than 5 mol% of Al_2O_3 , and 35-65 mol% of SiO_2 .

13. A substrate for an information recording medium, comprising a glass substance including, as glass components, 0.1-30 mol% of TiO_2 , 1-45 mol% of CaO , 5-40 mol% of $(\text{MgO}+\text{CaO})$, 3-30 mol% of $(\text{Na}_2\text{O}+\text{Li}_2\text{O})$, 0-less than 15 mol% of Al_2O_3 , and more than 55 mol% and up to 65 mol% of SiO_2 .

14. A substrate for an information recording medium, comprising a glass substance including, as glass components, 5-15 mol% of TiO_2 , 4-20 mol% of CaO , 5-30 mol% of $(\text{MgO}+\text{CaO})$, 5-22 mol% of $(\text{Na}_2\text{O}+\text{Li}_2\text{O})$, 0-8 mol% of Al_2O_3 , and 40-60 mol% of SiO_2 .

15. A substrate for an information recording medium as claimed in any one of claims 8 through 11, which includes transition metal oxide in place of a part or a whole of TiO_2 as a glass component.

16. A substrate for an information recording medium as claimed in claim 15, wherein said transition metal oxide is at least one oxide selected from a group consisting of oxides of Cr, Mn, Fe, Co, Ni, Ga, Ge, Y, Zr, Nb, Mo, La, Ce, Pr, Nd, Pm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Hf, Ta, and W.

17. A substrate for an information recording medium as claimed in claim 15, wherein said transition metal oxide is at least one oxide selected from a group consisting of oxides of Cr, V, and Zn.

18. A substrate for an information recording medium as claimed in claim 16 or 17, wherein said transition metal oxide has a content of 0.1-15 mol% and coexists with TiO_2 .

19. A substrate for an information recording medium as claimed in claim 16 or 17, wherein said transition metal

oxide has a content of 0.1-8 mol%.

20. A substrate for an information recording medium as claimed in claim 16, wherein said transition metal oxide coexisting with TiO_2 is Y_2O_3 and ZrO_2 .

21. A substrate for an information recording medium as claimed in claim 11 or 18, including 0.1-25 mol% of Li_2O .

22. A substrate for an information recording medium as claimed in claim 11 or 18, including 1-15 mol% of Na_2O .

23. A substrate for an information recording medium as claimed in claim 9 or 11, which is formed by the use of a mold.

24. A substrate as claimed in any one of claims 11 through 13, including as glass components at least 40 mol% of $(\text{SiO}_2 + \text{Al}_2\text{O}_3)$, at least 3 mol% of Li_2O , at least 5 mol% of $(\text{Na}_2\text{O} + \text{Li}_2\text{O})$, and at most 35 mol% of $(\text{CaO} + \text{MgO})$.

25. A substrate for an information recording medium, formed by chemically reinforcing the information recording medium claimed in any one of claims 7, 8, 11, 16, 18, and 20 or the glass substance thereof.

26. A substrate for an information recording medium as claimed in any one of claims 7, 8, 11, 16, 18, and 20, said substrate having a thermal expansion coefficient approximate to that of a material of a clamp for fixing the information recording medium in an information processing apparatus.

27. An information recording medium comprising the substrate claimed in any one of claims 7, 8, 11, 16, 18, and 20 and a recording layer formed on said substrate.

28. A substrate for an information recording medium, including glass components which achieve a Young's modulus not smaller than 100GPa and a liquidus temperature not higher than 1350 °C by the coexistence of Y_2O_3 and TiO_2 .

29. A substrate for an information recording medium as claimed in claim 28, wherein said glass components includes SiO_2 , Al_2O_3 , at least one of MgO and CaO, and Li_2O .

30. A substrate for an information recording medium as claimed in claim 29, wherein said glass components include 45-65 mol% of SiO_2 , 0-15 mol% of Al_2O_3 , 4-20 mol% of Li_2O , 0-8 mol% of Na_2O , 3-30 mol% of (Li_2O+Na_2O) , 0-21 mol% of CaO, 0-22 mol% of MgO, 4-40 mol% of $(CaO+MgO)$, 0-16 mol% of Y_2O_3 , and 1-15 mol% of TiO_2 .

31. A substrate for an information recording medium, comprising glass components which achieve a Young's modulus not smaller than 100GPa and a liquidus temperature not higher than 1350 °C by the coexistence of Y_2O_3 , TiO_2 , and ZrO_2 .

32. A substrate for an information recording medium as claimed in claim 31, wherein said glass components include SiO_2 , Al_2O_3 , at least one of MgO and CaO, and Li_2O .

33. A substrate for an information recording medium, comprising TiO_2 and at least one oxide selected from a rare earth metal oxide group consisting of Er_2O_3 , Nd_2O_3 , Sm_2O_3 , Eu_2O_3 , Gd_2O_3 , Tb_2O_3 , Dy_2O_3 , and Yb_2O_3 , and including glass components which achieve a Young's modulus not smaller than 100 GPa and a liquidus temperature not higher than 1350 °C.

34. A substrate for an information recording medium as claimed in claim 33, wherein said at least one oxide has a content of 5 mol%.

35. A substrate for an information recording medium as claimed in claim 34, wherein said glass components include SiO_2 , Al_2O_3 , at least one of MgO and CaO , and Li_2O and does not include Y_2O_3 .

36. An information recording device for recording/reproducing information, said device including a magnetic head and an information recording medium as claimed in claim 27.