

DESCRIPTION

Title of Invention: MAGNETIC RECORDING DEVICE AND LAYERED STRUCTURE

5 Technical Field

[0001] The present disclosure relates to a magnetic recording device and a stacked structure.

Background Art

[0002] With the recent development of computer technology, there has been a need for magnetic recording devices having a larger storage capacity and capable of saving space. Accordingly, a magnetic recording device includes a plurality of magnetic disks and spacers interposed therebetween, and a spindle is passed through inner holes of the magnetic disks and the spacers to form a stacked structure of the magnetic disks and the spacer. The magnetic disks and the spacers are fixed by being pressed by a clamp member from one side. In such a stack, the magnetic disks are not in contact with each other, and the magnetic disks are disposed at
10 predetermined positions so as to be spaced apart from each other. In the magnetic recording device, magnetic heads enter gaps between the magnetic disks that are spaced apart from each other, and a recording operation and the like are performed on the stacked magnetic disks using the magnetic heads (e.g., PTL1 to PTL3).

[0003] In order to increase the recording density of a magnetic layer, energy-assisted magnetic recording (EAMR) typified by heat-assisted magnetic recording (HAMR) and microwave-assisted magnetic recording (MAMR) is known as a recording method with which the recording density is increased by increasing the density of magnetic particles. In energy-assisted magnetic recording (EAMR), the size of magnetic particles is reduced to reduce the bit size, and, at the time of recording data, energy is applied to the magnetic particles to reduce the coercive
15 force, thus assisting magnetization reversal and increasing the recording density. In energy-assisted magnetic recording (EAMR), the track width is reduced due to the small size of magnetic particles, and the recording density in the track width direction is also improved.

Citation List

Patent Literatures

30 [0004] PTL1: JP 08-315533A

PTL2: JP 2000-57727A

PTL3: JP 2003-272336A

Summary of Invention

Technical Problem

5 [0005] Inside the magnetic recording device, high-speed rotation of the magnetic disks results in an increase in ambient temperature, whereby the magnetic disks are thermally expanded, followed by expansion of tracks toward the outer circumferential side. Accordingly, at the time of writing or reading data, the magnetic heads are radially displaced beyond the allowable range relative to the tracks, as a result of which an error is likely to occur. In energy-assisted magnetic
10 recording (EAMR), the track width is small, and the allowable displacement amount (off-track allowance) of the magnetic heads relative to the tracks is correspondingly small. Accordingly, a writing or reading error (R/W error) is likely to occur. On the other hand, also for positioning of the magnetic heads using servo information, the accuracy of the positioning is increased from the viewpoint of increasing the recording capacity, and thus a shape change of the magnetic disks
15 due to the temperature change may not be allowable. Therefore, the thermal expansion of the magnetic disks due to the temperature change is preferably as small as possible, and the coefficient of thermal expansion is required to be small in a wide temperature region from the viewpoint of ensuring the quality of the magnetic disks.

[0006] However, it has been found that, even in a case where the coefficient of thermal
20 expansion of the magnetic disks is within a predetermined range, deterioration in flatness of the magnetic disks in the state of being disposed in the magnetic recording device in combination with the spacers, and an increase of the occurrence of fluttering associated with such deterioration may cause a reading/writing error.

[0007] Therefore, it is an object of the present disclosure to provide a magnetic recording device
25 and a stacked structure that achieve high read/write accuracy.

Solution to Problem

[0008] An embodiment according to the present disclosure relates to a magnetic recording device including:

a plurality of magnetic disks each including a substrate and a magnetic recording layer
30 formed on the substrate; and

a spacer disposed between the plurality of magnetic disks, and configured to allow the magnetic disks to be stacked with a predetermined interval therebetween, wherein

an amount of change in flatness of the magnetic disks after the following thermal shock test is 5.0 μm or less.

5 [0009] An embodiment according to the present disclosure relates to a magnetic recording device including:

a plurality of magnetic disks each including a substrate and a magnetic recording layer formed on the substrate; and

10 a spacer disposed between the plurality of magnetic disks, and configured to allow the magnetic disks to be stacked with a predetermined interval therebetween, wherein

an amount of change in flatness of the magnetic disks after the following thermal shock test is 8.0 μm or less, and

a ratio (f/t value) of a value f (μm) of a flatness of the substrate to a thickness t (mm) of the substrate after the following thermal shock test is 20 $\mu\text{m}/\text{mm}$ or less.

15 [0010] An embodiment according to the present disclosure relates to a stacked structure including:

a plurality of magnetic disks each including a substrate and a magnetic recording layer formed on the substrate; and

20 a spacer disposed between the plurality of magnetic disks, and configured to allow the magnetic disks to be stacked with a predetermined interval therebetween, wherein

an amount of change in flatness of the magnetic disks after the following thermal shock test is 5.0 μm or less.

[0011] An embodiment according to the present disclosure relates to a stacked structure including;

25 a plurality of magnetic disks each including a substrate and a magnetic recording layer formed on the substrate; and

a spacer disposed between the plurality of magnetic disks, and configured to allow the magnetic disks to be stacked with a predetermined interval therebetween, wherein

30 an amount of change in flatness of the magnetic disks after the following thermal shock test is 8.0 μm or less, and

a ratio (f/t value) of a value f (μm) of a flatness of the substrate to a thickness t (mm) of the magnetic disk after the following thermal shock test is $20 \mu\text{m}/\text{mm}$ or less.

[0012] An embodiment according to the present disclosure relates to a stacked structure including:

5 a plurality of magnetic disks each including a substrate and a magnetic recording layer formed on the substrate; and

a spacer disposed between the plurality of magnetic disks, and configured to allow the magnetic disks to be stacked with a predetermined interval therebetween, wherein

an amount of change in flatness of the magnetic disks after the following thermal shock
10 test is $8.0 \mu\text{m}$ or less, and,

when an impact of $40 [\text{G}]$ is applied in $2 [\text{msec}]$ to the magnetic disks in a state of being mounted on the magnetic recording device after the following thermal shock test, in a normal direction of main surfaces of the magnetic disks, a maximum amplitude caused by vibrations of outer circumferential end portions of the magnetic disks in a thickness direction is 0.20 mm or
15 less.

[0013] <Thermal Shock Test>

In a thermal shock chamber, a heating and cooling program for holding the magnetic recording device at 70°C for 30 minutes, then cooling the magnetic recording device to -40°C in 2 minutes and holding the magnetic recording device for 30 minutes, and then heating the
20 magnetic recording device to 70°C in 2 minutes is repeated for 5 cycles.

Advantageous Effects of the Invention

[0014] According to the present invention, it is possible to provide a magnetic recording device and a stacked structure that achieve high read/write accuracy.

Description of Embodiments

25 [0015] [FIG. 1] FIG. 1 shows a schematic configuration diagram of a magnetic recording device according to the present embodiment.

[FIG. 2] FIG. 2 is a schematic cross-sectional view of a stacked structure.

[FIG. 3] FIG. 3 is a conceptual diagram showing a stacking structure.

[FIG. 4] FIG. 4 is an external perspective view of a magnetic disk according to the
30 present embodiment.

[FIG. 5] FIG. 5 is a cross-sectional view of the magnetic disk according to the present embodiment.

[FIG. 6] FIG. 6 is an external perspective view of a spacer according to the present embodiment.

5 Description of Embodiments

[0016] Preferred embodiments of the present disclosure will be described with reference to the accompanying drawings (Note that the components denoted by the same reference numerals in each of the drawings have identical or similar configurations). The embodiments described below serve to facilitate understanding of the present disclosure, and are not to be interpreted as
10 restricting the scope of the present disclosure. The elements included in the embodiments, and their arrangement, materials, conditions, shapes, sizes, and so forth may be appropriately modified without any limitation to the examples shown. In addition, the configurations described in different embodiments may also be partially replaced or combined with each other.

[0017] [Magnetic Recording Device]

15 A magnetic recording device according to a first embodiment includes:

a plurality of magnetic disks each including a substrate and a magnetic recording layer formed on the substrate; and

a spacer disposed between the plurality of magnetic disks, and configured to allow the magnetic disks to be stacked with a predetermined interval therebetween.

20 Also, in the magnetic recording device according to the first embodiment,
an amount of change in flatness of the magnetic disks after the following thermal shock test is 5.0 μm or less.

<Thermal Shock Test>

In a thermal shock chamber, a heating and cooling program for holding the magnetic
25 recording device at 70°C for 30 minutes, then cooling the magnetic recording device to -40°C in 2 minutes and holding the magnetic recording device for 30 minutes, and then heating the magnetic recording device to 70°C in 2 minutes is repeated for 5 cycles.

By including the above-described configuration, a magnetic recording device that achieves high read/write accuracy can be obtained.

30 [0018] From the viewpoint of further increasing the read/write accuracy, in the magnetic

recording device according to the first embodiment, the amount of change in flatness of the magnetic disks is 5.0 μm or less, preferably 4.0 μm or less, more preferably 3.0 or less, still more preferably 2.5 or less, yet more preferably 0 to 1.8, and even more preferably 0.1 to 1.5.

[0019] From the viewpoint of further increasing the read/write accuracy, in the magnetic recording device according to the first embodiment, a ratio (f/t value) of a value f (μm) of the flatness of the substrate to a thickness t (mm) of the substrate after the thermal shock test is preferably 25 $\mu\text{m}/\text{mm}$ or less, more preferably 0 to 20 $\mu\text{m}/\text{mm}$ or less, and still more preferably 5 to 18.5 $\mu\text{m}/\text{mm}$ or less.

[0020] A magnetic recording device according to a second embodiment includes:

a plurality of magnetic disks each including a substrate and a magnetic recording layer formed on the substrate; and

a spacer disposed between the plurality of magnetic disks, and configured to allow the magnetic disks to be stacked with a predetermined interval therebetween.

Also, in the magnetic recording device according to the second embodiment, an amount of change in flatness of the magnetic disks after the following thermal shock test is 8.0 μm or less, and

a ratio (f/t value) of a value f (μm) of a flatness of the substrate to a thickness t (mm) of the substrate after the following thermal shock test is 20 $\mu\text{m}/\text{mm}$ or less.

By including the above-described configuration, a magnetic recording device that achieves high read/write accuracy can be obtained. Even when the above-described amount of change in flatness is 8.0 μm or less, it is possible to increase the read/write accuracy by the f/t value being in the range of 20 $\mu\text{m}/\text{mm}$ or less.

[0021] From the viewpoint of further increasing the read/write accuracy, in the magnetic recording device according to the second embodiment, the amount of change in flatness of the magnetic disks is 8.0 μm or less, preferably 7.0 μm or less, more preferably 6.0 or less, still more preferably 5.0 or less, yet more preferably 0 to 4.0, and even more preferably 0.1 to 3.0. Even when the amount of change in flatness of the magnetic disks is in the above-described range, it is possible to further increase the read/write accuracy by a f/t value described below being in a predetermined range.

[0022] From the viewpoint of further increasing the read/write accuracy, in the magnetic

recording device according to the second embodiment, the ratio (f/t value) of the value f (μm) of the flatness of the substrate to the thickness t (mm) of the substrate after the thermal shock test is $20\ \mu\text{m}$ or less, preferably $18.5\ \mu\text{m}/\text{mm}$ or less, more preferably 0 to $18.5\ \mu\text{m}/\text{mm}$ or less, and still more preferably 5 to $18.5\ \mu\text{m}/\text{mm}$ or less.

5 [0023] A stacked structure according to a third embodiment includes:

a plurality of magnetic disks each including a substrate and a magnetic recording layer formed on the substrate; and

a spacer disposed between the plurality of magnetic disks, and configured to allow the magnetic disks to be stacked with a predetermined interval therebetween.

10 Also, in the stacked structure according to the third embodiment, an amount of change in flatness of the magnetic disks after the following thermal shock test is $8.0\ \mu\text{m}$ or less, and

a ratio (f/t value) of a value f (μm) of a flatness of the substrate to a thickness t (mm) of the magnetic disk after the following thermal shock test is $20\ \mu\text{m}/\text{mm}$ or less.

15 In the magnetic recording device according to the third embodiment, a preferred range of the ratio (f/t value) of the value f (μm) of the flatness of the substrate to the thickness t (mm) of the substrate after the thermal shock test is the same as the range shown in the second embodiment described above.

[0024] A stacked structure according to a fourth embodiment includes:

20 a plurality of magnetic disks each including a substrate and a magnetic recording layer formed on the substrate; and

a spacer disposed between the plurality of magnetic disks, and configured to allow the magnetic disks to be stacked with a predetermined interval therebetween, wherein

an amount of change in flatness of the magnetic disks after the following thermal shock test is $8.0\ \mu\text{m}$ or less, and,

25 when an impact of $40\ [\text{G}]$ is applied in $2\ [\text{msec}]$ to the magnetic disks in a state of being mounted on the magnetic recording device after the following thermal shock test, in a normal direction of main surfaces of the magnetic disks, a maximum amplitude caused by vibrations of outer circumferential end portions of the magnetic disks in a thickness direction is $0.20\ \text{mm}$ or less.

30 [0025] For the stacked structure according to the fourth embodiment, it is preferable that, when

an impact of 40 [G] is applied in 2 [msec] to the magnetic disks in a state of being mounted on the magnetic recording device, in a normal direction of main surfaces of the magnetic disks, a maximum amplitude caused by vibrations of outer circumferential end portions of the magnetic disks in a thickness direction is 0.20 mm or less. The aforementioned maximum amplitude is preferably 0.18 mm or less, and more preferably 0.16 mm or less. Such a range makes it possible to suppress generation of particles as a result of magnetic disks being chipped even if a magnetic disk comes into contact with another magnetic disk due to vibration caused by an impact from the outside, or comes into contact with another member. Note that the above-described impact test is performed using an AVEX-SM-110-MP-type tester manufactured by AR BROWN Co., Ltd.

[0026] The above-described thermal shock test is performed according to the following procedure.

In a thermal shock chamber, a heating and cooling program for holding a magnetic recording device at 70°C for 30 minutes, then cooling the magnetic recording device to -40°C in 2 minutes and holding the magnetic recording device for 30 minutes, and then heating the magnetic recording device to 70°C in 2 minutes is repeated for 5 cycles.

As the thermal shock chamber, a thermal shock chamber available under the trade name "TSA-503EL-W" (manufactured by ESPEC CORP.) can be used, for example. In the thermal shock test, a magnetic recording device including a plurality of magnetic disks, and a spacer incorporated therein is used.

[0027] Note that the amount of change in flatness of the magnetic disks can be adjusted by adjusting a combination of the material and the thickness of substrates of the magnetic disks, and the material of the spacer. More specifically, a predetermined amount of change in flatness can be obtained by adjusting the material of the substrate of the magnetic disks, and the coefficient of thermal expansion and the Young's modulus of the material of the spacer, and adjusting the combination thereof. The values of the above-described parameters can be adjusted by adjusting the shape of the spindle and the force of the clamp, in addition to adjusting the materials of the magnetic disks and the spacer.

[0028] Note that, as the f/t value, the values within the above-described range can be obtained by adjusting the above-described amount of change in flatness, and the thickness t of the substrate.

[0029] Hereinafter, configurations that are common to the first embodiment and the second embodiment are referred to as the configurations according to the present embodiment.

Preferably, the spacer satisfies an expression: $\text{CTE (spa)} \cdot \text{E (spa)} \leq 1.0 \times 10^4$. By satisfying the expression: $\text{CTE (spa)} \cdot \text{E (spa)} \leq 1.0 \times 10^4$, the magnetic recording device has a further improved impact resistance and further improved fluttering characteristics.

CTE (spa)·E (spa) is preferably 0.8×10^4 or less, more preferably within the range from 0.1×10^4 to 0.7×10^4 , and still more preferably within the range from 0.2×10^4 to 0.4×10^4 .

[0030] Preferably, the substrate satisfies an expression: $\text{CTE (sub)} \cdot \text{E (sub)} \leq 0.5 \times 10^4$. By satisfying the expression: $\text{CTE (sub)} \cdot \text{E (sub)} \leq 0.5 \times 10^4$, the magnetic recording device has a further improved impact resistance and further improved fluttering characteristics.

CTE (sub)·E (sub) is preferably 0.45×10^4 or less, more preferably within the range from 0.10×10^4 to 0.40×10^4 , and still more preferably within the range from 0.20×10^4 to 0.35×10^4 .

[0031] Preferably, the substrate satisfies an expression: $\text{CTE (sub)}/\text{E (sub)} \leq 1.5$. By satisfying the expression: $\text{CTE (sub)}/\text{E (sub)} \leq 1.5$, the fluttering characteristics of the magnetic recording device under a usage environment of the magnetic recording device can be kept low even when the substrate has a thickness of 0.51 mm or less.

The value of CTE (sub)/E (sub) is 1.5 or less, preferably 0.8 or less, and more preferably within the range from 0.35 to 0.5.

[0032] CTE (sub) is a coefficient of thermal expansion ($\times 10^{-7}/\text{K}$) of the substrate at 100 to 300°C. The amount of change in length in a predetermined temperature range from a sample cut out to have dimensions of a length of 50 mm and a width of 10 mm is determined using a thermal dilatometer based on laser interferometry, and used as the value of the average coefficient of linear expansion at 100 to 300°C. Note that a magnetic film included in a magnetic disk has a negligible effect on the thermal expansion, and therefore the coefficient of thermal expansion of the magnetic disk may be used as the coefficient of thermal expansion of the substrate. Note that further details of the measurement method are described in the examples.

[0033] CTE (spa) is a coefficient of thermal expansion ($\times 10^{-7}/\text{K}$) of the spacer at 100 to 300°C. In measuring the coefficient of thermal expansion of the spacer, a conductive film on an outer surface is removed from the spacer in case where a sample having the same dimensions as the

substrate cannot be cut out. Then, a sample that has been ground is washed and dried, then remelted at a predetermined temperature to have the same dimensions as the substrate, and the measurement is performed using the sample.

[0034] E (sub) is a Young's modulus (GPa) of the substrate. The Young's modulus can be measured in accordance with JIS R 1602:1995. A test piece for measurement is cut out from a magnetic disk into a rectangular parallelepiped having a length of 50 mm, a width of 10 mm, and the same thickness as the thickness of the magnetic disk, and the measurement can be performed at room temperature. Note that a magnetic film included in a magnetic disk has a negligible effect on the thermal expansion, and therefore the coefficient of thermal expansion of the magnetic disk can be used as the coefficient of thermal expansion of the substrate.

[0035] E (spa) is a Young's modulus (GPa) of the spacer. The Young's modulus can be measured in accordance with JIS R 1602:1995. As a test piece for the measurement of the spacer, a conductive film on an outer surface is removed from the spacer, and thereafter a sample that has been ground is washed and dried, then remelted at a predetermined temperature. The sample is cut out into a rectangular parallelepiped having the same thickness as the magnetic disk, and subjected to the measurement at room temperature.

[0036] Hereinafter, a magnetic recording device according to the present embodiment will be described in detail.

FIG. 1 shows a schematic configuration diagram of the magnetic recording device according to the present embodiment. A magnetic recording device 1 includes a stacked structure 2 of a plurality of magnetic disks 21. In the magnetic recording device 1 according to the embodiment, the stacked structure 2 is mounted to a spindle motor (not shown). The magnetic disks 21 of the stacked structure 2 are rotated by the spindle motor.

[0037] A head assembly 3 includes head sliders 31. In the head assembly 3, the head sliders 31 are provided in a plurality of stages. The head sliders 31 each include a magnetic head in the vicinity of a distal end thereof. The head sliders 31 record and reproduce information onto and from the corresponding rotating magnetic disks 21. As a result of the head sliders 31 being provided in a plurality of stages, it is possible to read information from the magnetic disks 21 stacked with a predetermined interval therebetween. As this time, the magnetic disks 21 are less likely to cause deformation of substrates thereof due to temperature change in the usage

environment, or have an increased impact resistance. Consequently, the head sliders or the magnetic heads are less likely to interfere with the magnetic disks during recording or reading of information.

[0038] FIG. 2 is a schematic cross-sectional view of the stacked structure. The stacked structure 2 includes a plurality of magnetic disks 21, and spacers 22 disposed between the plurality of magnetic disks 21, and configured to allow the magnetic disks 21 to be stacked with a predetermined interval therebetween. Although FIG. 2 shows an example in which the stacked structure 2 includes three magnetic disks 21, the number of magnetic disks 21 is not particularly limited.

[0039] As shown in FIG. 2, the plurality of magnetic disks 21 are inserted around a rotating spindle 23 with the spacers 22 interposed therebetween, and a stacked structure 2 of the magnetic disks 21 and the spacers 22 is fixed to the spindle 23 by being pressed from above by a clamp member 24 fixed with screws or the like, whereby the magnetic disks 21 are attached with predetermined intervals. The clamp member 24 presses the uppermost magnetic disk 21. Then, the pressing force also presses and fixes the entire stack. The clamp member 24 includes a circular projection 241 for pressing the magnetic disks 21 around the central axis of the spindle 23.

[0040] As shown in FIG. 3, the magnetic disks 21 and the spacers 22 are alternately arranged on top of each other to form a stacked structure, and incorporated into a magnetic storage device.

[0041] FIG. 4 is an external perspective view of a magnetic disk 21 according to the present embodiment. The magnetic disk 21 forms a circular ring shape, and has a spindle hole 215. The magnetic disk 21 includes main surfaces 216 opposing each other. The pair of main surfaces are substantially parallel to each other. Here, "substantially parallel" means that the parallelism is 5 μm or less, for example.

[0042] FIG. 5 is a cross-sectional view of the magnetic disk 21 according to the present embodiment. The magnetic disk 21 includes a substrate 211 having a thickness of 0.51 mm or less, and magnetic recording layers 213.

[0043] Preferably, the substrate has a thickness of 0.51 mm or less. The thickness of the substrate is preferably 0.50 mm or less, more preferably 0.30 to 0.50 mm, and still more preferably 0.32 to 0.45 mm.

[0044] Examples of the material of the substrate include metal materials such as stainless steel, titanium, aluminum, and an aluminum alloy, and ceramic materials, and glass. Among these, a glass substrate is preferred as the substrate.

[0045] The glass composition of the glass substrate preferably contains

5 SiO₂ in an amount of 55 to 80 mol%, Al₂O₃ in an amount of 5 to 25 mol%, B₂O₃ in an amount of 0 to 8 mol%, P₂O₅ in an amount of 0 to 5 mol%, MO in an amount of 5 to 25 mol% (MO is at least one selected from MgO, CaO, SrO, and BaO, and a content thereof is the sum of the contents of MgO, CaO, SrO, and BaO), and M₂O in an amount of 0 to 15 mol% (M₂O is at least one selected from Li₂O, Na₂O, and K₂O, and the content thereof is the sum of Li₂O, Na₂O, and K₂O). The glass composition of the glass substrate may be composed of these components.

[0046] Preferred contents of the components of the glass composition of the glass substrate are as follows.

[0047] SiO₂ is a network-forming component in glass. From the viewpoints of increasing the stability of the glass and improving the meltability during production, the content of SiO₂ is preferably 55 to 80 mol%, more preferably 57 to 75 mol%, and still more preferably 60 to 70 mol%.

[0048] From the viewpoints of improving the heat resistance of the glass and increasing the stability of the glass, the content of Al₂O₃ is preferably 5 to 25 mol%, more preferably 10 to 20 mol%, and still more preferably 12 to 18 mol%.

20 [0049] B₂O₃ is a network-forming component in glass. The content of B₂O₃ is preferably 0 to 8 mol%, more preferably 0.1 to 5 mol%, and still more preferably 0.1 to 3 mol%.

[0050] The content of P₂O₅ is preferably 0 to 5 mol%, more preferably 0 to 3 mol%, and still more preferably 0 to 2 mol%.

[0051] MO is at least one selected from MgO, CaO, SrO, and BaO, and the content thereof is the sum of the contents of MgO, CaO, SrO, and BaO. From the viewpoint of adjusting the Young's modulus, the content of MO is preferably 5 to 25 mol%, more preferably 6 to 20 mol%, and still more preferably 14 to 18 mol%.

From the viewpoint of adjusting the Young's modulus, the content of MgO is preferably 3 to 20 mol%, more preferably 4 to 19 mol%, and still more preferably 8 to 18 mol%.

30 [0052] From the viewpoint of improving the productivity, the content of CaO is preferably 0 to

10 mol%, more preferably 0 to 8 mol%, and still more preferably 0 to 6 mol%.

[0053] From the viewpoint of reducing the specific gravity of the glass, the content of SrO is preferably 0 to 5 mol%, more preferably 0 to 3 mol%, and still more preferably 0 to 1.5 mol%.

[0054] From the viewpoint of reducing the specific gravity of the glass, the content of BaO is preferably 0 to 5 mol%, more preferably 0 to 4 mol%, and still more preferably 0 to 1.5 mol%.

[0055] M₂O is at least one selected from Li₂O, Na₂O, and K₂O, and the content thereof is the sum of Li₂O, Na₂O, and K₂O. The content of M₂O is preferably 0 to 15 mol%, more preferably 0 to 10 mol%, and still more preferably 0.5 to 9 mol%.

[0056] From the viewpoint of improving the heat resistance, the content of Li₂O is preferably 0 to 5 mol%, more preferably 0 to 7 mol%, and still more preferably 0.5 to 6 mol%.

[0057] The content of Na₂O is preferably 0 to 10 mol%, more preferably 0 to 7 mol%, and still more preferably 0.5 to 5 mol%.

[0058] The content of K₂O is preferably 0 to 3 mol%, more preferably 0 to 1 mol%, and still more preferably 0 to 0.3 mol%.

[0059] Note that the substrate is a glass substrate,
the glass substrate satisfies an expression (5): $\text{CTE (sub)}/\text{E (sub)} \leq 1.5 \cdots (5)$,
the glass composition of the glass substrate preferably contains

SiO₂ in an amount of 55 to 80 mol%, Al₂O₃ in an amount of 5 to 25 mol%, B₂O₃ in an amount of 0 to 8 mol%, MO in an amount of 5 to 25 mol% (MO is at least one selected from MgO, CaO, SrO, and BaO, and the content thereof is the sum of the contents of MgO, CaO, SrO, and BaO), and M₂O in an amount of 0 to 15 mol% (M₂O is at least one selected from Li₂O, Na₂O, and K₂O, and the content thereof is the sum of Li₂O, Na₂O, and K₂O).

[0060] Examples of the glass composition of the glass substrate include SU1, SU2, and SU3 described below.

[0061] SU1: Alkali-free glass containing SiO₂ in an amount of 60 to 70 mol%, Al₂O₃ in an amount of 8 to 15 mol%, B₂O₃ in an amount of 1 to 5 mol%, MO in an amount of 10 to 20 mol% (MO is at least one selected from MgO, CaO, SrO, and BaO, and the content thereof is the sum of the contents of MgO, CaO, SrO, and BaO), and M₂O in an amount of 0 to 1 mol% (M₂O is at least one selected from Li₂O, Na₂O, and K₂O, and the content thereof is the sum of Li₂O, Na₂O, and K₂O).

[0062] SU2: Alkali-free glass containing SiO₂ in an amount of 60 to 70 mol%, Al₂O₃ in an amount of 8 to 15 mol%, B₂O₃ in an amount of 1 to 5 mol%, MO in an amount of 10 to 20 mol% (MO is at least one selected from MgO, CaO, SrO, and BaO, and the content thereof is the sum of the contents of MgO, CaO, SrO, and BaO.), and M₂O in an amount of 0 to 1 mol% (M₂O is at least one selected from Li₂O, Na₂O, and K₂O, and the content thereof is the sum of Li₂O, Na₂O, and K₂O).

[0063] SU3: Alkali-containing glass containing SiO₂ in an amount of 55 to 75 mol%, Al₂O₃ in an amount of 5 to 20 mol%, B₂O₃ in an amount of 0 to 3 mol%, MO in an amount of 12 to 25 mol% (MO is at least one selected from MgO, CaO, SrO, and BaO, and the content thereof is the sum of the contents of MgO, CaO, SrO, and BaO), and M₂O in an amount of 0.1 to 10 mol% (M₂O is at least one selected from Li₂O, Na₂O, and K₂O, and the content thereof is the sum of Li₂O, Na₂O, and K₂O.)

[0064] In the present disclosure, the glass composition is shown as a glass composition on an oxide basis. Here, "glass composition on an oxide basis" refers to a glass composition obtained by conversion to oxides assuming that all of the starting materials of glass have decomposed during melting and are present as oxides in the glass.

The glass composition in the present disclosure can be determined, for example, by a method such as inductively coupled plasma-atomic emission spectrometry (ICP-AES). Using ICP-AES, quantitative analysis is separately performed for each of the elements. Then, analysis values are converted into expressions on an oxide basis. Analysis values obtained by ICP-AES may include, for example, a measurement error of approximately $\pm 5\%$ of an analysis value. Therefore, a value on an oxide basis expression converted from an analysis value may also include an error of approximately $\pm 5\%$.

In the present disclosure, the content of a constituent component being 0 mol% means that the constituent component is substantially not contained, and the content of the constituent component is approximately less than or equal to an impurity level. "Approximately less than or equal to an impurity level" means being less than 0.01 mol%, for example.

[0065] The coefficient of thermal expansion CTE (sub) (unit: $\times 10^{-7}/\text{K}$) of the substrate at 100 to 300°C is preferably 10 to 110, more preferably 25 to 98, and still more preferably 30 to 55.

[0066] The Young's modulus E (sub) (unit: GPa) of the substrate is preferably 75 to 120, more

preferably 80 to 110, and still more preferably 85 to 105.

[0067] The value of the specific modulus E/d of the substrate is preferably $32.0 \times 10^6 \text{ m}^2/\text{s}^2$ or more, more preferably $33.5 \times 10^6 \text{ m}^2/\text{s}^2$ or more, and preferably $35.0 \times 10^6 \text{ m}^2/\text{s}^2$ or more. The impact resistance is further improved by the substrate having a specific modulus E/d within the
 5 aforementioned range. Note that the above-described effect can be more significantly achieved by the substrate having a value of the specific modulus E/d within the above-described range when the substrate has a thickness of 0.51 mm or less. The specific modulus E/d refers to a value obtained by dividing a Young's modulus by a specific gravity.

[0068] Each of the magnetic disks 21 includes the magnetic recording layers 213. The
 10 magnetic disk 21 may include, for example, on a main surface of a smoothly polished glass substrate, an adhesive layer, an underlayer, a magnetic recording layer (magnetic layer), a protection layer, and a lubricating layer that are stacked in this order from the side closer to the main surface.

Among these, the adhesive layer, the underlayer, and the magnetic recording layer are
 15 formed, for example, by introducing the glass substrate into a film forming device that has been evacuated, and sequentially forming these layers onto a main surface of the glass substrate in an Ar atmosphere by direct current (DC) magnetron sputtering. It is possible to use, for example, CrTi as the adhesive layer, and it is possible to use, for example, a material containing Ru or MgO as the underlayer. Note that a soft magnetic layer and a heat sink layer may be added as
 20 needed. After the above-described film formation, a lubricating layer can be formed by forming a protection layer using C_2H_4 , for example, by chemical vapor deposition (CVD), performing nitriding for introducing nitrogen into the surface in the same chamber, and then applying, for example, perfluoropolyether (PFPE) onto the protection layer by dip coating. In this manner, a magnetic disk 21 can be produced.

[0069] In order to achieve higher density recording for the magnetic disk 21, it is preferable
 25 that the magnetic recording layer contains a magnetic material having high magnetic anisotropy energy. Examples of the magnetic material that is preferred in this respect include an Fe-Pt-based magnetic material or a Co-Pt-based magnetic material. Note that "-based" here means containing.

[0070] That is, it is preferable that the magnetic disk 21 includes a magnetic recording layer
 30

containing Fe and Pt, or Co and Pt. As for magnetic recording layer containing such a magnetic material, and a method for forming the same, a reference can be made to WO 2011/019010. In addition, a magnetic disk 21 including such a magnetic recording layer is preferably applied to a magnetic recording device using a recording method called energy-assisted magnetic recording (EAMR). Among energy-assisted recording methods, a method in which magnetization reversal is assisted by irradiation of near-field light or the like is called heat-assisted magnetic recording (HAMR), and a method in which magnetization reversal is assisted using a microwave is called microwave-assisted magnetic recording (MAMR). As for the details of these methods, a reference can be made to WO 2011/019010. Note that a CoPtCr-based material may be used as the magnetic material for forming the magnetic recording layer.

[0071] FIG. 6 is an external perspective view of a spacer 22 according to the present embodiment. The spacer 22 forms a circular ring shape, and has a spindle hole 225. The spacer 22 includes main surfaces 226 opposing each other. The pair of main surfaces are substantially parallel to each other. Here, substantially parallel means that the parallelism is 5 μm or less, for example.

[0072] Examples of the material of the spacer include metal materials such as stainless steel, titanium, aluminum, and an aluminum alloy, and ceramic materials, and glass. Among these, a glass spacer is preferred as the spacer.

[0073] The glass composition of the spacer preferably contains

SiO₂ in an amount of 55 to 88 mol%, Al₂O₃ in an amount of 0 to 20 mol%, B₂O₃ in an amount of 1 to 30 mol%, P₂O₅ in an amount of 0 to 5 mol%, MO in an amount of 0 to 20 mol% (MO is at least one selected from MgO, CaO, SrO, and BaO, and the content thereof is the sum of the contents of MgO, CaO, SrO, and BaO), and M₂O in an amount of 0 to 15 mol% (M₂O is at least one selected from Li₂O, Na₂O, and K₂O, and the content thereof is the sum of Li₂O, Na₂O, and K₂O). The glass composition of the glass substrate may be composed of these components. Note that the glass composition of the spacer preferably has a composition different from the glass composition of the substrate.

[0074] Preferred contents of the components of the glass composition of the spacer are as follows.

[0075] SiO₂ is a network-forming component in glass. From the viewpoints of increasing the

stability of the glass and improving the meltability during production, the content of SiO_2 is preferably 55 to 88 mol%, more preferably 65 to 85 mol%, and still more preferably 75 to 85 mol%.

[0076] From the viewpoints of improving the heat resistance of the glass and increasing the stability of the glass, the content of Al_2O_3 is preferably 0 to 20 mol%, more preferably 1 to 17 mol%, and still more preferably 1 to 5 mol%.

[0077] B_2O_3 is a network-forming component in glass. The content of B_2O_3 is preferably 1 to 30 mol%, more preferably 5 to 28 mol%, still more preferably 8 to 28 mol%, and yet more preferably 10 to 20 mol%.

[0078] The content of P_2O_5 is preferably 0 to 5 mol%, more preferably 0 to 3 mol%, and still more preferably 0 to 2 mol%.

[0079] MO is at least one selected from MgO, CaO, SrO, and BaO, and the content thereof is the sum of the contents of MgO, CaO, SrO, and BaO. From the viewpoint of adjusting the Young's modulus, the content of MO is preferably 0 to 20 mol%, more preferably 0 to 5 mol%, and still more preferably 0 mol%.

From the viewpoint of adjusting the Young's modulus, the content of MgO is preferably 0 to 10 mol%, more preferably 0 to 5 mol%, and still more preferably 0 mol%.

[0080] From the viewpoint of improving the productivity, the content of CaO is preferably 0 to 10 mol%, more preferably 0 to 5 mol%, and still more preferably 0 mol%.

[0081] From the viewpoint of reducing the specific gravity of the glass, the content of SrO is preferably 0 to 4 mol%, more preferably 0 to 3 mol%, and still more preferably 0 mol%.

[0082] From the viewpoint of reducing the specific gravity of the glass, the content of BaO is preferably 0 to 5 mol%, more preferably 0 to 3 mol%, and still more preferably 0 mol%.

[0083] M_2O is at least one selected from Li_2O , Na_2O , and K_2O , and the content thereof is the sum of Li_2O , Na_2O , and K_2O . The content of M_2O is preferably 0 to 15 mol%, more preferably 0 to 10 mol%, and still more preferably 0.1 to 8 mol%.

[0084] From the viewpoint of improving the heat resistance, the content of Li_2O is preferably 0 to 4 mol%, more preferably 0 to 3 mol%, and still more preferably 0 to 2 mol%.

[0085] The content of Na_2O is preferably 0 to 15 mol%, more preferably 0.1 to 10 mol%, and still more preferably 1 to 5 mol%.

[0086] The content of K₂O is preferably 0 to 3 mol%, more preferably 0 to 2 mol%, and still more preferably 0.1 to 0.5 mol%.

[0087] Note that the spacer is a glass substrate,
the glass substrate satisfies an expression (5): $CTE (sub)/E (sub) \leq 1.5 \cdots (5)$,

5 it is preferable that the glass composition of the spacer contains

SiO₂ in an amount of 55 to 88 mol%, Al₂O₃ in an amount of 0 to 20 mol%, B₂O₃ in an amount of 1 to 30 mol%, MO in an amount of 0 to 20 mol% (MO is at least one selected from MgO, CaO, SrO, and BaO, and the content thereof is the sum of the contents of MgO, CaO, SrO, and BaO), and M₂O in an amount of 0 to 15 mol% (M₂O is at least one selected from Li₂O, Na₂O, and K₂O, and the content thereof is the sum of Li₂O, Na₂O, and K₂O), and that the glass composition of the spacer is a composition different from the glass composition of the substrate of the magnetic disk.

[0088] Examples of the glass composition of the spacer include SP-1 described below.

15 [0089] SP-1: Borosilicate glass containing SiO₂ in an amount of 78 to 88 mol%, Al₂O₃ in an amount of 1 to 5 mol%, B₂O₃ in an amount of 10 to 28 mol%, MO in an amount of 3 to 8 mol% (MO is at least one selected from MgO, CaO, SrO, and BaO, and the content thereof is the sum of the contents of MgO, CaO, SrO, and BaO), and M₂O in an amount of 0 to 5 mol% (M₂O is at least one selected from Li₂O, Na₂O, and K₂O, and the content thereof is the sum of Li₂O, Na₂O, and K₂O).

20 [0090] Preferably, the spacer includes a spacer substrate made of glass, and a conductive film on an outer surface of the spacer substrate. The conductor film may be a conductive oxide such as SnO₂ (tin oxide), ZnO, In₂O₃, or indium tin oxide (ITO). Note that the conductive film may be any of the above-described conductive oxides doped with fluorine. The conductive film may be a metal film. Examples of the components of the metal film include chromium, titanium, 25 tantalum, tungsten, alloys containing these metals, and nickel alloys such as NiP (nickel phosphorus) and NiW (nickel tungsten). Preferably, the nickel alloy is nonmagnetic. The conductive film is formed by dipping used for plating such as electroless plating, vapor deposition, sputtering, or the like.

[0091] The coefficient of thermal expansion CTE (spa) (unit: $\times 10^{-7}/K$) of the spacer at 100 to 30 300°C is preferably 10 to 105, more preferably 25 to 95, and still more preferably 30 to 45.

[0092] The Young's modulus E (spa) (unit: GPa) of the spacer is preferably 30 to 120, more preferably 50 to 80, and still more preferably 50 to 75.

[0093] Examples of preferred combinations of the glass substrate and the spacer include SU1 and SP1, SU2 and SP1, and SU3 and SP1. With the aforementioned combinations, the deformation of the substrate due to temperature change in the usage environment is less likely to occur.

[0094] Examples of the material of the spindle include aluminum and stainless steel. Of these, aluminum is preferred from the viewpoint of the weight reduction. Preferably, the magnetic disks 21 and the spacers 22 are fixed to a spindle made of aluminum or stainless steel. A spindle made of aluminum is lightweight as described above, but tends to have a high coefficient of thermal expansion, and a low Young's modulus. However, with the combination of the magnetic disk and the spacer according to the present embodiment, the deformation of the substrate due to temperature change in the usage environment is less likely to occur.

[0095] It is preferable that, when an impact of 40 [G] is applied in 2 [msec] to the magnetic disks in a state of being mounted on the magnetic recording device, in a normal direction of main surfaces of the magnetic disks, a maximum amplitude caused by vibrations of outer circumferential end portions of the magnetic disks in a thickness direction is 0.25 mm or less. The aforementioned maximum amplitude is preferably 0.23 mm or less, and more preferably 0.18 mm or less. Such a range makes it possible to suppress generation of particles as a result of the magnetic disks being chipped even if a magnetic disk comes into contact with another magnetic disk due to vibration caused by an impact from the outside, or comes into contact with another member. Note that the above-described impact test is performed using an AVEX-SM-110-MP-type tester manufactured by AR BROWN Co., Ltd.

[0096] As described above, according to the present embodiment, it is possible to provide a magnetic recording device and a stacked structure that achieve high read/write accuracy.

Examples

[0097] In the following, the present embodiment will be described in further detail by way of examples. However, the present embodiment is not limited to the following examples.

[0098] <Coefficient of Thermal Expansion>

As for the coefficient of thermal expansion of the substrate, the amount of change in

length in a predetermined temperature range from a sample cut out from the magnetic disk to have dimensions of a length of 50 mm and a width of 10 mm was determined using a thermal dilatometer based on laser interferometry, and used as the value of the average coefficient of linear expansion at 100 to 300°C. Note that a magnetic film included in a magnetic disk has a negligible effect on the thermal expansion, and therefore the coefficient of thermal expansion of the magnetic disk was used as the coefficient of thermal expansion of the substrate.

Note that, in measuring the coefficient of thermal expansion of the spacer, a sample having the same dimensions as the magnetic disk cannot be cut out. Accordingly, the spacer is melted by heating, then poured into a flat mold, and slowly cooled to room temperature at a speed of 50°C/10 min or less, to give a glass plate having a thickness of 0.5 mm. Then, the measurement can be performed using a sample cut out to have dimensions of a length of 50 mm and a width of 10 mm. Note that samples can be produced using a plurality of spacers as long as the spacers have the same composition.

[0099] <Young's Modulus >

The Young's modulus E of the substrate was measured in accordance with JIS R 1602:1995. A test piece for the measurement was cut out from the magnetic disk into a rectangular parallelepiped having a length of 50 mm, a width of 10 mm, and the same thickness as the thickness of the magnetic disk, and subjected to the measurement at room temperature. Note that a magnetic film included in a magnetic disk has a negligible effect on the thermal expansion, and therefore the coefficient of thermal expansion of the magnetic disk was used as the coefficient of thermal expansion of the substrate.

Note that, in measuring the Young's modulus of the spacer, a sample having the same dimensions as the magnetic disk cannot be cut out. Accordingly, the spacer is melted by heating, then poured into a flat mold, and slowly cooled to room temperature at a speed of 50°C/10 min or less, to give a glass plate having a thickness of 0.5 mm. Then, the measurement can be performed using a sample cut out to have dimensions of a length of 50 mm and a width of 10 mm. Note that samples can be produced using a plurality of spacers as long as the spacers have the same composition.

[0100] <Specific Gravity>

The specific gravity was measured by the Archimedes method.

[0101] The magnetic film has a negligible effect on the coefficient of thermal expansion, the Young's modulus, and the density (specific gravity) of the magnetic disk, and therefore the coefficient of thermal expansion, the Young's modulus, and the density (specific gravity) of the magnetic disk can be used as the coefficient of thermal expansion, the Young's modulus E , and the density (specific gravity) of the substrate.

[0102] <Specific Modulus E/d >

The specific modulus E/d was calculated by dividing the Young's modulus by the specific gravity.

[0103] <Flatness>

The flatness of the magnetic disks was measured as the maximum height difference (PV value) of the surface of the magnetic disk using OptiFlat manufactured by Phaseshift Technologies, based on interference fringes generated by a semiconductor laser.

As the flatness of the magnetic disks, the flatness of the magnetic disk located at the top in the magnetic recording device was measured in a state in which a plurality of magnetic disks are stacked and fixed with spacers interposed therebetween. Note that objects (the cover of the magnetic recording device, a lamp member, etc.) that could hinder the measurement were removed from the magnetic recording device in advance.

[0104] <Thermal Shock Test and Amount of Change in Flatness>

The thermal shock test was performed using a thermal shock chamber "TSA-503EL-W" (trade name, manufactured by ESPEC CORP.). The magnetic recording device was placed in the chamber, and a heating and cooling program for holding the magnetic recording device at 70°C for 30 minutes, then cooling the magnetic recording device to -40°C in 2 minutes and holding the magnetic recording device for 30 minutes, and then heating the magnetic recording device to 70°C in 2 minutes was repeated for 5 cycles. For the magnetic disks in the magnetic recording device after the test, the flatness was measured using the above-described measurement method. The amount of change in flatness of the magnetic disk before and after the thermal shock test was indicated as an absolute value.

[0105] <Maximum Amplitude>

<Impact Test: Maximum Amplitude>

The impact test was performed using an AVEX-SM-110-MP-type tester manufactured

by AR BROWN Co., Ltd.

An impact of 40 [G] was applied in 2 [msec] to the magnetic disks in the state of being mounted in the magnetic recording device, in the normal direction of the main surfaces of the magnetic disks. The maximum amplitude caused by vibrations of outer circumferential end portions of the magnetic disks in the thickness direction was recorded, and the impact performance was evaluated.

[0106] (Examples and Comparative Examples)

In Example 1, the thermal shock test, the measurement of the amount of change in flatness, the maximum amplitude, and the maximum amount of displacement were performed using a magnetic recording device mounting a stacked body formed by stacking the following nine magnetic disks with the following spacers interposed therebetween. Note that, in the other examples and comparative examples, the thermal shock test, and the measurement of the amount of change in flatness and the maximum amplitude were performed using magnetic recording devices for which the substrates and the spacers used for the magnetic disks were changed as shown in Table 1. The results are shown in Table 1.

Spacers: An outer circumferential surface had a diameter of 32 mm, an inner circumferential surface had a diameter of 25 mm, and a thickness was 1.8 mm; the chamfered surface had a length in the radial direction of 250 μ m on both the inner and outer circumferential sides, and had an angle of 45 degrees relative to the inner and outer circumferential surfaces. The width L of the main surface was 3.0 mm.

Magnetic disks: A magnetic film and so forth were formed on a substrate having a diameter of 97 mm, an inner diameter of 25 mm, and a thickness of 0.5 mm.

For the other examples and the comparative examples, evaluation was performed in the same manner as in Example 1, using the spacers and the substrates shown in Table 1. The results are shown in Table 1.

[0107]

[Table 1]

	Spacer			Substrate					Impact test	Thermal shock test		
	Material	CTE ($\times 10^7/\text{K}$)	Young's modulus (GPa)	Material	Thickness t (mm)	CTE ($\times 10^7/\text{K}$)	Young's modulus (GPa)	Specific modulus E/d	Maximum amplitude	Amount of change in flatness (μm)	Flatness f after test (μm)	f/t after test ($\mu\text{m}/\text{mm}$)
Com. Ex. 1	SP-1	94	71	SU-1	0.5	37	83	32.5	0.23	10.6	17.0	34.0
Com. Ex. 2	SP-4	93	116	SU-2	0.45	95	79	33.7	0.25	6.0	15.1	33.6
Example 1	SP-1	94	71	SU-2	0.5	95	79	33.7	0.21	2.2	9.0	18.0
Example 2	SP-2	33	65	SU-1	0.5	37	83	32.5	0.18	2.8	11.5	23.0
Example 3	SP-2	33	65	SU-3	0.45	45	90	36.5	0.15	1.8	7.2	16.0
Example 4	SP-1	94	71	SU-2	1.27	95	79	33.7	0.16	7.5	23.2	18.3
Com. Ex. 3	SP-3	225	69	SU-1	0.5	37	83	32.5	0.23	9.0	17.2	34.4
Example 5	SP-3	225	69	SU-2	0.5	95	79	33.7	0.21	4.3	11.8	23.6
Com. Ex. 4	SP-3	225	69	SU-2	1.27	95	79	33.7	0.16	14.9	31.5	24.8

[0108] The meanings of the various symbols in the table are as follows:

(Substrate)

SU-1: Glass substrate (made of alkali-free glass having a Young's modulus of 83 GPa and a coefficient of thermal expansion of $37 \times 10^{-7}/\text{K}$)

5 SU-2: Glass substrate (made of alkali-containing glass having a Young's modulus of 79 GPa and a coefficient of thermal expansion of $95 \times 10^{-7}/\text{K}$)

SU-3: Glass substrate (made of alkali-containing glass having a Young's modulus of 90 GPa and a coefficient of thermal expansion of $45 \times 10^{-7}/\text{K}$)

(Spacer)

10 SP-1: Glass spacer (made of glass having a Young's modulus of 71 GPa and a coefficient of thermal expansion of $94 \times 10^{-7}/\text{K}$)

SP-2: Glass spacer (made of a glass having a Young's modulus of 65 GPa and a coefficient of thermal expansion of $33 \times 10^{-7}/\text{K}$)

15 SP-3: Metal spacer (made of Al metal having a Young's modulus of 69 GPa and a coefficient of thermal expansion of $225 \times 10^{-7}/\text{K}$)

SP-4: Metal spacer (made of Ti metal having a Young's modulus of 116 GPa and a coefficient of thermal expansion of $93 \times 10^{-7}/\text{K}$)

Reference Signs List

[0109] 1 ... magnetic recording device, 2 ... stacked structure, 21 ... magnetic disk, 22 ...
20 spacer, 23 ... spindle, 24 ... clamp member, 211 ... substrate, 213 ... magnetic recording layer,
215 ... spindle hole, 216 ... main surface, 225 ... spindle hole, 226 ... main surface, 241 ...
projection, 3 ... head assembly, 31 ... head slider

CLAIMS

[Claim 1] A magnetic recording device comprising:

a plurality of magnetic disks each including a substrate and a magnetic recording
5 layer formed on the substrate; and

a spacer disposed between the plurality of magnetic disks, and configured to allow
the magnetic disks to be stacked with a predetermined interval therebetween, wherein

an amount of change in flatness of the magnetic disks after the following thermal
shock test is $5.0\text{ }\mu\text{m}$ or less,

10 <Thermal Shock Test>

in a thermal shock chamber, a heating and cooling program for holding the magnetic
recording device at 70°C for 30 minutes, then cooling the magnetic recording device to -
 40°C in 2 minutes and holding the magnetic recording device for 30 minutes, and then
heating the magnetic recording device to 70°C in 2 minutes is repeated for 5 cycles.

15

[Claim 2] A magnetic recording device comprising:

a plurality of magnetic disks each including a substrate and a magnetic recording
layer formed on the substrate; and

a spacer disposed between the plurality of magnetic disks, and configured to allow
20 the magnetic disks to be stacked with a predetermined interval therebetween, wherein

an amount of change in flatness of the magnetic disks after the following thermal
shock test is $8.0\text{ }\mu\text{m}$ or less, and

a ratio (f/t value) of a value f (μm) of a flatness of the substrate to a thickness t (mm)
of the substrate after the following thermal shock test is $20\text{ }\mu\text{m/mm}$ or less,

25 <Thermal Shock Test>

in a thermal shock chamber, a heating and cooling program for holding the magnetic
recording device at 70°C for 30 minutes, then cooling the magnetic recording device to -
 40°C in 2 minutes and holding the magnetic recording device for 30 minutes, and then
heating the magnetic recording device to 70°C in 2 minutes is repeated for 5 cycles.

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[Claim 3] The magnetic recording device according to claim 1 or 2, wherein
the substrate has a thickness of 0.51 mm or less, and has a value of a specific
modulus E/d of $32.0 (\times 10^6 \text{ m}^2/\text{s}^2)$ or more.

5 [Claim 4] The magnetic recording device according to claim 1 or 2, wherein
the spacer includes a spacer substrate made of glass, and a conductive film on an
outer surface of the spacer substrate.

[Claim 5] The magnetic recording device according to claim 1 or 2, wherein
10 the magnetic disks and the spacer are fixed to a spindle made of aluminum.

[Claim 6] The magnetic recording device according to claim 1 or 2, wherein,
assuming that CTE (sub) is a coefficient of thermal expansion ($\times 10^{-7}/\text{K}$) of the
substrate in a temperature range from 100 to 300°C, CTE (spa) is a coefficient of thermal
15 expansion ($\times 10^{-7}/\text{K}$) of the spacer in the temperature range from 100 to 300°C, E (sub) is a
Young's modulus (GPa) of the substrate, and E (spa) is a Young's modulus (GPa) of the
spacer,

the spacer satisfies an expression: $\text{CTE (spa)} \cdot \text{E (spa)} \leq 1.0 \times 10^4$, and

the substrate satisfies an expression: $\text{CTE (sub)} \cdot \text{E (sub)} \leq 0.5 \times 10^4$.

20

[Claim 7] The magnetic recording device according to claim 1 or 2, wherein
the substrate is a glass substrate,

the glass substrate satisfies an expression (5):

$$\text{CTE (sub)}/\text{E (sub)} \leq 1.5 \cdots (5)$$

25

(where

CTE (sub) is a coefficient of thermal expansion ($\times 10^{-7}/\text{K}$) of the substrate in a
temperature range from 100 to 300°C, and

E (sub) is a Young's modulus (GPa) of the substrate),

a glass composition of the glass substrate contains

30

SiO_2 in an amount of 55 to 80 mol%, Al_2O_3 in an amount of 5 to 25 mol%, B_2O_3 in

an amount of 0 to 8 mol%, MO in an amount of 5 to 25 mol% (MO is at least one selected from MgO, CaO, SrO, and BaO, and a content thereof is the sum of contents of MgO, CaO, SrO, and BaO), and M₂O in an amount of 0 to 15 mol% (M₂O is at least one selected from Li₂O, Na₂O, and K₂O, and a content thereof is the sum of Li₂O, Na₂O, and K₂O).

5

[Claim 8] The magnetic recording device according to claim 1 or 2, wherein,
when an impact of 40 [G] is applied in 2 [msec] to the magnetic disks in a state of being mounted on the magnetic recording device, in a normal direction of main surfaces of the magnetic disks, a maximum amplitude caused by vibrations of outer circumferential end portions of the magnetic disks in a thickness direction is 0.25 mm or less.

10

[Claim 9] A stacked structure comprising:

a plurality of magnetic disks each including a substrate and a magnetic recording layer formed on the substrate; and

15

a spacer disposed between the plurality of magnetic disks, and configured to allow the magnetic disks to be stacked with a predetermined interval therebetween, wherein

an amount of change in flatness of the magnetic disks after the following thermal shock test is 5.0 μm or less,

<Thermal Shock Test>

20

in a thermal shock chamber, a heating and cooling program for holding the magnetic recording device at 70°C for 30 minutes, then cooling the magnetic recording device to -40°C in 2 minutes and holding the magnetic recording device for 30 minutes, and then heating the magnetic recording device to 70°C in 2 minutes is repeated for 5 cycles.

25

[Claim 10] A stacked structure comprising;

a plurality of magnetic disks each including a substrate and a magnetic recording layer formed on the substrate; and

a spacer disposed between the plurality of magnetic disks, and configured to allow the magnetic disks to be stacked with a predetermined interval therebetween, wherein

30

an amount of change in flatness of the magnetic disks after the following thermal

shock test is $8.0\ \mu\text{m}$ or less, and

a ratio (f/t value) of a value f (μm) of a flatness of the substrate to a thickness t (mm) of the magnetic disk after the following thermal shock test is $20\ \mu\text{m}/\text{mm}$ or less,

<Thermal Shock Test>

- 5 in a thermal shock chamber, a heating and cooling program for holding the magnetic recording device at 70°C for 30 minutes, then cooling the magnetic recording device to -40°C in 2 minutes and holding the magnetic recording device for 30 minutes, and then heating the magnetic recording device to 70°C in 2 minutes is repeated for 5 cycles.

- 10 [Claim 11] A stacked structure comprising:

a plurality of magnetic disks each including a substrate and a magnetic recording layer formed on the substrate; and

a spacer disposed between the plurality of magnetic disks, and configured to allow the magnetic disks to be stacked with a predetermined interval therebetween, wherein

- 15 an amount of change in flatness of the magnetic disks after the following thermal shock test is $8.0\ \mu\text{m}$ or less, and,

when an impact of $40\ [\text{G}]$ is applied in $2\ [\text{msec}]$ to the magnetic disks in a state of being mounted on the magnetic recording device after the following thermal shock test, in a normal direction of main surfaces of the magnetic disks, a maximum amplitude caused by vibrations of outer circumferential end portions of the magnetic disks in a thickness direction is $0.20\ \text{mm}$ or less,

<Thermal Shock Test>

- 25 in a thermal shock chamber, a heating and cooling program for holding the magnetic recording device at 70°C for 30 minutes, then cooling the magnetic recording device to -40°C in 2 minutes and holding the magnetic recording device for 30 minutes, and then heating the magnetic recording device to 70°C in 2 minutes is repeated for 5 cycles.