

DESCRIPTION

TITLE OF THE INVENTION:

ALUMINUM SUBSTRATE FOR MAGNETIC RECORDING MEDIA

TECHNICAL FIELD

[0001]

The present invention relates to an aluminum substrate used as a substrate of a magnetic recording medium, where an SiO_2 film suitable for formation of a magnetic film at high temperatures is deposited.

BACKGROUND ART

[0002]

A magnetic recording medium used in various electronic devices such as computer has a non-magnetic substrate having formed thereon a magnetic film working out to a recording layer. The substrate for a magnetic recording medium is required to have light weight, high hardness, smooth surface and scratch resistance. Therefore, an aluminum plate is used as a non-magnetic and lightweight material enabling a smooth surface to be easily obtained by mirror processing, etc., and a substrate having deposited thereon an Ni-P plating film (hereinafter, sometimes referred to as "Ni-P plated aluminum substrate") for ensuring surface hardness and scratch resistance of an aluminum plate is being used as a general-purpose substrate for a magnetic recording medium.

[0003]

With the recent trend toward a magnetic recording medium having a large capacity, a next-generation magnetic medium for drastically increasing the recording density is being developed. As a technique for increasing the recording density, a heat-assisted magnetic recording system of recording data while heating a recording medium with a laser is attracting attention.

[0004]

In the process of producing a magnetic recording medium suitable for the heat-assisted magnetic recording system, the substrate temperature reaches 300°C or

more, furthermore, 350°C or more, due to heat hysteresis during production, such as magnetic film deposition temperature, and high heat resistance is required of a substrate for a magnetic recording medium. To meet this requirement, heat resistance of the aluminum plate is also improved, and as disclosed, for example, in Patent Documents 1 and 2, various aluminum plates excellent in heat resistance at high temperatures of 500°C or more have been proposed. In the case of an Ni-P-plated aluminum substrate used at present for general purposes, the aluminum plate serving as a base material has a heat resistance of 370°C or more. However, the Ni-P-plated film is crystallized to have magnetism when heated at 300°C or more and therefore, can practically cope with a temperature only up to about 300°C, and the heat resistance temperature of the Ni-P-plated film significantly restricts the production of a magnetic recording medium.

[0005]

As a film capable of replacing the Ni-P-plated film, an amorphous SiO₂ film disclosed, for example, in Patent Documents 3 and 4 is being studied.

PRIOR ART LITERATURE

PATENT DOCUMENT

[0006]

Patent Document 1: Japanese Patent No. 5325869

Patent Document 2: JP-A-2013-151737

Patent Document 3: Japanese Patent No. 2552682

Patent Document 4: JP-B-S53-37202

SUMMARY OF THE INVENTION

PROBLEMS THAT THE INVENTION IS TO SOLVE

[0007]

The SiO₂ film is non-magnetic and has high hardness and excellent property in terms of heat resistance, and attention is focused thereon. However, when the SiO₂ film is deposited as a thick film so as to ensure scratch resistance, there arises a problem, for example, that cracking occurs in the SiO₂ film by heating at about 300°C or the SiO₂ film flakes away from the aluminum plate. Thus, an SiO₂ film satisfied

with both scratch resistance and heat resistance has not yet been provided, and utilization of this film in the magnetic recording field such as heat-assisted magnetic recording system is restricted.

[0008]

The present invention has been made by focusing attention on these circumstances, and an object of the present invention is to provide an aluminum substrate for a magnetic recording medium, where an SiO₂ film having excellent properties in terms of heat resistance and scratch resistance is deposited.

MEANS FOR SOLVING THE PROBLEMS

[0009]

The aluminum substrate for a magnetic recording medium which is capable of solving the above problem(s) is an aluminum substrate including an SiO₂ film deposited on both surfaces of the aluminum substrate, in which the SiO₂ film has a thickness of 6.0 μm or more and 15.0 μm or less and a compressive stress of 450 MPa or more and 1,000 MPa or less.

[0010]

In addition, an aluminum substrate for a magnetic recording medium in the present invention includes an SiO₂ film deposited on both surfaces of the aluminum substrate, the SiO₂ film having a thickness of 6.0 μm or more and 15.0 μm or less and a compressive stress of 450 MPa or more and 1,000 MPa or less, and the SiO₂ film has been deposited by a vapor deposition method by heating a aluminum plate at 200°C or more and 370°C or less.

[0011]

It is preferable embodiment that the vapor deposition method is a plasma CVD method.

ADVANTAGEOUS EFFECTS OF THE INVENTION

[0012]

The aluminum substrate for a magnetic recording medium of the present invention, where an SiO₂ film having predetermined thickness and compressive stress is deposited, has excellent properties in terms of heat resistance and scratch resistance.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013]

[FIG. 1] FIG. 1 is a plan view of the hollow disk-shaped disk manufactured in Examples.

[FIG. 2] FIG. 2 is a plan view of the hollow disk-shaped disk in which the warp amount measuring direction is depicted.

[FIG. 3] FIG. 3 is a graph illustrating the relationship between the film thickness and the scratch depth.

MODE FOR CARRYING OUT THE INVENTION

[0014]

The present invention is described below. In the present invention, the "aluminum plate" indicates a state before depositing an SiO_2 film, and the "aluminum substrate" indicates a state after depositing an SiO_2 film and in this description, is sometimes simply referred to as "substrate". In the present invention, the "aluminum" encompasses pure aluminum and an aluminum alloy.

[0015]

The "temperature of the aluminum plate during the deposition" is a temperature of the aluminum plate itself during the deposition of an SiO_2 film and is a temperature measured by installing a thermocouple on the aluminum plate. In this description, the above temperature is sometimes simply referred to as "deposition temperature".

[0016]

In the present invention, since the temperature of the aluminum plate or aluminum substrate is measured, the preset temperature of, for example, a device or atmosphere when depositing an SiO_2 film, a magnetic film, etc. may not agree with the temperature of the aluminum plate or aluminum substrate. For example, in Examples of the present invention, for evaluating the heat resistance of an aluminum substrate having deposited thereon an SiO_2 film, the temperature of a heating furnace is set such that the temperature of the aluminum substrate becomes a temperature simulating the heat hysteresis in the production process, by previously installing a thermocouple on

the aluminum substrate and examining the relationship between the temperature inside the heating surface and the temperature of the aluminum substrate. Consequently, the temperature of the heating furnace may not agree with the temperature of the aluminum substrate.

[0017]

As described above, when the SiO₂ film is deposited as a thick film so as to ensure scratch resistance, cracking or flaking occurs in the SiO₂ film by heating at about 300°C and therefore, it is difficult to satisfy both scratch resistance and heat resistance.

[0018]

As a result of the studies by the present inventors, the present inventors have found that scratch resistance equivalent to that of the case where an Ni-P-plated film is formed can be imparted to the SiO₂ film by setting the thickness of the SiO₂ film to 6.0 μm or more and furthermore, heat resistance can also be improved by adjusting the compressive stress of the SiO₂ film.

[0019]

The present inventors have made many intensive studies from various angles on the cause of occurrence of cracking or flaking when the SiO₂ film is deposited as a thick film. As a result, it has been found that a tensile stress due to thermal expansion of the aluminum plate is imposed on the SiO₂ film in a high-temperature environment and since the yield strength for tensile stress decreases as the thickness of the SiO₂ film is larger, cracking or flaking occurs at about 300°C.

[0020]

More specifically, it is known that the coefficient of thermal expansion of aluminum is substantially around $24 \times 10^{-6}/K$ and a linear expansion of about 1% occurs by a temperature rise of 400°C. On the other hand, as for the coefficient of thermal expansion of SiO₂, the coefficient of thermal expansion is known to be about 1×10^{-7} to $1 \times 10^{-6}/K$, and the linear expansion of SiO₂ is about one-several tenths of the linear expansion of aluminum. Accordingly, a tensile force acts on the SiO₂ film due to a difference in the thermal expansion between the aluminum plate and the SiO₂ film. It is considered that the SiO₂ film deposited as a thick film is reduced in the yield

strength for tensile force to exceed the breaking strength at about 300°C and cracking or flaking readily occurs in the SiO₂ film.

[0021]

The present inventors have made many studies to prevent the SiO₂ film from cracking or flaking due to thermal expansion. As a result, it has been found that when the compressive stress acting on the SiO₂ film at room temperature is increased, the load of tensile stress due to thermal expansion can be reduced and cracking or flaking in the SiO₂ film can be suppressed. The present invention has been accomplished based on this finding.

[0022]

More specifically, when an aluminum substrate having deposited thereon an SiO₂ film subject to the action of a compressive stress is heated, the SiO₂ film is stretched along with thermal expansion of the aluminum substrate. However, thermal expansion acts in a direction of relaxing the compressed state by an amount of compressive stress produced in the SiO₂ film at room temperature and therefore, the tensile force actually imposed on the SiO₂ film is reduced. As a result, the SiO₂ film is considered to become resistant to cracking or flaking compared with conventional films, and exhibit a heat resistance of preferably 350°C or more, more preferably 400°C or more, still more preferably 500°C or more.

[0023]

The configuration of the aluminum substrate for a magnetic recording medium of the present invention is specifically described below.

[0024]

[Thickness of SiO₂ Film: 6.0 μm or more and 15.0 μm or less]

When the SiO₂ film is thin, even if the hardness is high, the scratch resistance is not sufficient for the film to function as a protective film, and a defect is readily occurred in a magnetic recording medium. In order to impart sufficient scratch resistance to an extent such that the occurrence of a physical defect, e.g., scratch and dent, can be prevented even when receiving an impact during production or use, the thickness of the SiO₂ film needs to be 6.0 μm or more. The thickness of the SiO₂ film is preferably 7.5 μm or more, more preferably 9.0 μm or more. On the other hand, the upper limit of the film thickness is not particularly limited from the standpoint of

enhancing the scratch resistance, but when the thickness of the SiO₂ film is too large, the yield strength for tensile stress due to thermal expansion is reduced. For this reason, the film thickness is 15.0 μm or less, preferably 13.0 μm or less.

[0025]

In the case of polishing the SiO₂ film so as to ensure the desired surface smoothness, it is preferable to determine the thickness of the SiO₂ film deposited by taking the polishing amount into consideration and achieve the film thickness in the range above after polishing.

[0026]

[Compressive Stress of SiO₂ Film: 450 MPa or more and 1,000 MPa or less]

When the compressive stress acting on the SiO₂ film is low, when the temperature of the aluminum substrate reaches about 300°C, there arises a problem regarding the heat resistance, for example, cracking occurs in the SiO₂ film due to thermal expansion or the SiO₂ film flakes away from the aluminum substrate. Accordingly, the compressive stress of the SiO₂ film having the above-described thickness needs to be 450 MPa or more. The compressive stress of the SiO₂ film is preferably 550 MPa or more, more preferably 600 MPa or more. The compressive stress of the SiO₂ film is preferably higher from the standpoint of decreasing the tensile stress, but when the compressive stress is too high, when the SiO₂ film is deposited on the aluminum plate and then cooled to room temperature, the SiO₂ film is broken by compression to cause cracking or flaking. For this reason, the compressive stress of the SiO₂ film needs to be lower than the compression breaking strength of the SiO₂ film and is, specifically, 1,000 MPa or less, preferably 900 MPa or less.

[0027]

In the present invention, the method for calculating the compressive stress of the SiO₂ film is as follows. First, an SiO₂ film is deposited on both surfaces of an aluminum plate such that film stresses on both surfaces of the aluminum substrate are balanced to cancel out the bending moment. The amount of warp Δw produced after removing part δ of the SiO₂ film on one surface is measured, and while the bending moment ΔM having caused the warp is calculated from the following formula (12), the compressive stress σ acting on the SiO₂ film is determined from the following formula (11).

[0028]

Specifically, the compressive stress acting on the SiO₂ can be determined according to calculation expressions represented by the following formulae (1) and (2) relating to the deflection amount at a time when a bending moment acts on a hollow disk-shaped aluminum substrate, described in "Deformation of Aluminum Alloy Plates for Disks" (The Japan Society for Precision Engineering, Vol. 41, No. 11, pp. 1055-1059, 1975; Atsunobu Une and Toshio Kasai).

[0029]

[Math. 1]

$$w(r) = -\frac{M_0 \cdot (r^2 - 4b^2)}{2 \cdot (1 + \nu) \cdot D} \quad \dots \text{formula (1)}$$

[0030]

[Math. 2]

$$D = \frac{E \cdot h^3}{12 \cdot (1 - \nu^2)} \quad \dots \text{formula (2)}$$

[0031]

In the formulae, r is the distance (m) from the center of a disk, b is the inner diameter (m) of a hollow disk, provided that in the case of a non-hollow disk, $b=0$, h is the thickness (m) of aluminum plate, E is the Young's modulus (Pa), ν is the Poisson's ratio, D is the flexural rigidity, and M_0 is the bending moment (N). As the Young's modulus and the Poisson's ratio, Young's modulus: $E=70 \text{ GPa}$ ($7.0 \times 10^{10} \text{ Pa}$) and Poisson's ratio: $\nu=0.33$, described in Aluminum Handbook (compiled by Japan Aluminium Association, 6th edition, issued October, 2001), were used.

[0032]

The bending moment M_0 is represented by the following formula (3). In the formula, a is the position coordinate in the thickness direction of the substrate, and d is the film thickness (m).

[0033]

[Math. 3]

$$M_0 = - \int_0^{h+2d} \sigma(a) \cdot \left(a - \frac{h+2d}{2} \right) da \quad \dots \text{formula (3)}$$

[0034]

The bending moment M_0 taking into account the bending moment due to compressive stress of the SiO_2 film is represented by the following formulae (4) and (5).

[0035]

[Math. 4]

$$M_0 = -\sigma \int_0^d \left(a - \frac{h+2d}{2} \right) da - \sigma \int_{h+d}^{h+2d} \left(a - \frac{h+2d}{2} \right) da \quad \dots \text{formula (4)}$$

[0036]

[Math. 5]

$$M_0 = -\sigma \left[\frac{a^2}{2} - \frac{a(h+2d)}{2} \right]_0^d - \sigma \left[\frac{a^2}{2} - \frac{a(h+2d)}{2} \right]_{h+d}^{h+2d} \quad \dots \text{formula (5)}$$

[0037]

The first member of the right side above is represented by the following formula (6).

[0038]

[Math. 6]

$$\begin{aligned} & -\sigma \left[\frac{d^2}{2} - \frac{d(h+2d)}{2} \right] - 0 \\ & = -\sigma \left(\frac{-dh - d^2}{2} \right) \\ & = \sigma \left(\frac{dh + d^2}{2} \right) \quad \dots \text{formula (6)} \end{aligned}$$

[0039]

The second member of the right side is represented by the following formula (7).

[0040]

[Math. 7]

$$\begin{aligned} & -\sigma \left[\frac{(h+2d)^2}{2} - \frac{(h+2d)(h+2d)}{2} \right] + \sigma \left[\frac{(h+d)^2}{2} - \frac{(h+d)(h+2d)}{2} \right] \\ & = 0 + \sigma \left[\frac{h^2 + 2dh + d^2}{2} - \frac{h^2 + 2dh + dh + 2d^2}{2} \right] \\ & = \sigma \left(\frac{-dh - d^2}{2} \right) \end{aligned}$$

$$= -\sigma \left(\frac{dh + d^2}{2} \right) \quad \dots \text{formula (7)}$$

[0041]

Accordingly, the bending moment is $M_0=0$, and the compressive stresses of the SiO_2 film deposited on both surfaces of the aluminum substrate are balanced and cancel one another. In this state, part of the SiO_2 film on one surface, corresponding to a portion to a depth δ (m) out of the as-deposited thickness, is removed, as a result, the balance of the compressive stresses is lost to generate a bending moment ΔM represented by the following formula (8).

[0042]

[Math. 8]

$$\Delta M = -\sigma \left[\frac{a^2}{2} - \frac{a(h+2d)}{2} \right]_0^d - \sigma \left[\frac{a^2}{2} - \frac{a(h+2d)}{2} \right]_{h+d}^{h+2d-\delta} \quad \dots \text{formula (8)}$$

[0043]

The first member of the right side of formula (8) is the same as the first member of the right side of formula (5) and therefore, is represented by formula (6), but the second member of the right side of formula (8) is represented by the following formula (9).

[0044]

[Math. 9]

$$\begin{aligned} & -\sigma \left[\frac{(h+2d-\delta)^2}{2} - \frac{(h+2d-\delta)(h+2d)}{2} \right] + \sigma \left[\frac{(h+d)^2}{2} - \frac{(h+d)(h+2d)}{2} \right] \\ & = -\sigma \left[\frac{h^2 + 4d^2 + \delta^2 + 4d \cdot h - 2\delta \cdot h - 4\delta \cdot d}{2} - \frac{h^2 + 2dh + 2dh + 4d^2 - \delta \cdot h - 2\delta \cdot d}{2} \right] \\ & + \sigma \left[\frac{h^2 + 2dh + d^2}{2} - \frac{h^2 + 2dh + dh + 2d^2}{2} \right] \\ & = -\sigma \left[\frac{\delta^2 - \delta \cdot h - 2\delta \cdot d}{2} \right] + \sigma \left[\frac{-dh - d^2}{2} \right] \quad \dots \text{formula (9)} \end{aligned}$$

[0045]

From formula (6) and formula (9), the bending moment ΔM is represented by the following formula (10).

[0046]

[Math. 10]

$$\Delta M = \sigma \left(\frac{dh + d^2}{2} \right) - \sigma \left(\frac{\delta^2 - \delta \cdot h - 2\delta \cdot d}{2} \right) + \sigma \left(\frac{-dh - d^2}{2} \right)$$

$$\Delta M = \sigma \frac{\delta \cdot h + 2\delta \cdot d - \delta^2}{2} \quad \dots \text{formula (10)}$$

[0047]

Here, since [thickness h of aluminum plate]>>[film thickness d]>[depth δ of SiO₂ film removed], the bending moment ΔM generated when part of the SiO₂ film is removed by δ from one surface is represented by the following formula (11).

[0048]

[Math. 11]

$$\Delta M = \frac{\sigma \cdot \delta \cdot h}{2} \quad \dots \text{formula (11)}$$

[0049]

This is equivalent to the bending moment when an SiO₂ film having a stress of $-\sigma$ is deposited to a thickness δ .

[0050]

On the other hand, since the warp amount Δw is represented by the difference in the deflection amount between an inner-diameter position and an outer-diameter position of the substrate, assuming that the position in the inner diameter part of the substrate is r_{in} and the position in the outer diameter part of the substrate is r_{out} , the difference in the warp amount Δw between before and after removal of part of the SiO₂ film is represented by the following formula (12) based on formula (1).

[0051]

[Math. 12]

$$\Delta w = w(r_{out}) - w(r_{in})$$

$$\Delta w = -\frac{\Delta M(r_{out}^2 - r_{in}^2)}{2 \cdot (1 + \nu) \cdot D} \quad \dots \text{formula (12)}$$

[0052]

The warp amount Δw generated when part of the SiO₂ film is removed by δ from one surface is measured using formulae (11) and (12), whereby the compressive stress σ acting on the SiO₂ film can be determined. In the case where a compressive stress is acting on the SiO₂ film, when one surface is polished to remove the film by δ , the balance of stresses is lost and the polished surface changes into a concave surface.

[0053]

When the SiO₂ film of the present invention is deposited only on one surface of the aluminum plate, depending on the kind of the aluminum plate, warping occurs in the aluminum substrate due to a compressive stress of the SiO₂ film. Accordingly, the SiO₂ film needs to be deposited on both surfaces of the aluminum plate so as to suppress warp of the aluminum substrate. In the present invention, the thickness of the SiO₂ film may be equalized between respective surfaces to balance the bending moment resulting from compressive stress.

[0054]

The production method of the aluminum substrate for a magnetic recording medium according to the present invention is described below.

[0055]

The aluminum plate used as the base material in the present invention is not particularly limited and may be either a pure aluminum plate or an aluminum alloy plate. For example, 5086 alloy and 2219 alloy described in JIS H4000: 2006, an aluminum alloy plate described in Patent Document 1 "containing 3.5 mass% or more and 6 mass% or less of Mg, with the remainder consisting of Al and unavoidable impurities, which is obtained by performing flat baking under the conditions that the temperature is raised at a temperature rise rate of 2°C/min or less until reaching 360°C or more, held at 360°C or more for 2 hours or more, and then lowered at a temperature drop rate of 2°C/min or less, wherein the variation in the flatness between before and after heating at 500°C for 10 seconds is 5 μm or less and the variation in the average crystal grain size between before and after heating at 500°C for 10 seconds is 10 μm or less", and an aluminum alloy plate described in Patent Document 2 "which is an aluminum alloy substrate for a magnetic disk, containing Mg: 3.5 mass% or more and 6 mass% or less, with the remainder consisting of Al and unavoidable impurities, wherein the variation in the flatness before and after heating at 500°C for 10 seconds is 5 μm or less", are preferred. Among these, 2219 alloy and the aluminum alloy plates described in Patent Documents 1 and 2 are more preferred because of their excellent high-temperature heat resistance.

[0056]

The theoretical formula for use in the film stress measurement employed in the present invention holds true under the condition that the thickness of the SiO₂ film

is sufficiently small compared with the thickness of the aluminum plate. This theoretical formula is preferably applied, for example, when the thickness of the aluminum plate is 30 times or more, more preferably 50 times or more, the thickness of the SiO₂ film. There is also required the condition that the thickness of the aluminum plate is sufficiently small compared with the diameter of the aluminum plate. The theoretical formula is preferably applied, for example, when the diameter of the aluminum plate is 20 times or more, more preferably 30 times or more, the thickness of the aluminum plate.

[0057]

The thickness of the aluminum substrate is not particularly limited, and those having various thicknesses may be used, but usually, the thickness of the aluminum plate and the thickness of the SiO₂ film may be appropriately set so that the aluminum substrate can be finished to a predetermined thickness required as a magnetic recording medium. For example, for a magnetic recording medium of $\phi 95$ mm, a 1.270 mm-thick or 1.753 mm-thick aluminum substrate may be used, and for a magnetic recording medium of $\phi 65$ mm, a 0.635 mm-thick or 0.800 mm-thick aluminum substrate may be used.

[0058]

It is recommended that the aluminum plate has been subjected to punching in a desired shape and an annealing treatment. By applying an annealing treatment, distortion due to processing can be removed, and the flatness can be improved.

[0059]

Since a surface altered layer resulting from rolling, etc. is formed on the surface of the aluminum plate, it is preferable to remove the surface altered layer by turning with a lathe or a working method such as grinding work or by a combination of both and smoothen the surface of the aluminum plate. If the surface roughness of the aluminum plate is too large, even when the SiO₂ film is polished, a desired surface smoothness may not be obtained. For this reason, the surface is preferably made smooth.

[0060]

The working method is not particularly limited and in general, wet grinding using a polyvinyl alcohol grinding stone or turning using a diamond cutting tool may

be employed. In addition, after turning, wet grinding using a polyvinyl alcohol grinding stone may be performed.

[0061]

The surface roughness of the aluminum plate is, for example, in terms of the centerline average roughness Ra specified in JIS B0601: 2001, preferably 20 nm or less, more preferably 12 nm or less.

[0062]

[Deposition of SiO₂ Film]

The conditions for deposition of the SiO₂ film are not particularly limited as long as the thickness of the SiO₂ film deposited on the aluminum plate is 6.0 μm or more and 15.0 μm or less and the compressive stress is 450 MPa or more and 1,000 MPa or less. The SiO₂ film according to the present invention is preferably deposited by a vapor deposition method by heating the aluminum plate at a temperature of 200°C or more and 370°C or less.

[0063]

The thickness of the SiO₂ film is very small as compared with the thickness of the aluminum plate and therefore, the elongation of the SiO₂ film is governed by thermal expansion of the aluminum plate. On the other hand, the coefficient of thermal expansion of the SiO₂ film is one-several tenths of that of the aluminum plate and along with thermal expansion or thermal shrinkage of the aluminum plate, the SiO₂ film is stretched or compressed. In general, the SiO₂ film has strong resistance to compression, but its resistance to stretch is weak. When the SiO₂ film on the aluminum plate can be subject to the action of a compressive stress at room temperature, even if the SiO₂ film is stretched due to thermal expansion of the aluminum plate, the tensile force acting on the SiO₂ film is relieved by the action of a compressive stress. In addition, the stress acting on the SiO₂ film formed on the aluminum plate is governed by the deposition method or condition, and among others, the temperature has a strong effect. In the case where the film is deposited at a high temperature, the aluminum plate is heat-shrunk in the process of cooling to room temperature, and a compressive stress is produced in the SiO₂ film. Even when reheated, merely the compressive stress acting on the SiO₂ film is relieved, and substantially no tensile force acts, though the aluminum plate may thermally expand

until the deposition temperature from room temperature. If the aluminum substrate is heated over the deposition temperature, a tensile force acts on the SiO₂ film due to thermal expansion between the deposition temperature and the heating temperature. Accordingly, in the case where the deposition temperature of the SiO₂ film is high, when the SiO₂ film has yield strength for stretch occurring between the deposition temperature of the SiO₂ film and the heating temperature after the deposition of SiO₂ film, cracking or the like is not occurred. As a result, in the case of depositing the SiO₂ film at a high temperature as compared with the case of the deposition at room temperature, cracking or flaking due to the difference in the coefficient of thermal expansion is considered to be less likely occurred in the SiO₂ film. This reveals that sufficient heat resistance may be imparted by raising the deposition temperature of the SiO₂ film.

[0064]

[Deposition of SiO₂ Film: Vapor Deposition Method]

The SiO₂ film of the present invention is deposited by a vapor deposition method. The vapor deposition method is preferred, because the film thickness is easily controlled and in addition, uniform and dense deposition is facilitated. Examples of the vapor deposition method include a physical vapor deposition method (PVD: physical vapor deposition) such as sputtering and vapor deposition, and a chemical vapor deposition method (CVD) such as plasma chemical vapor growth method (plasma-enhanced chemical vapor deposition: hereinafter, sometimes referred to as "plasma CVD method"). Among these, a chemical vapor deposition method facilitating deposition to a desired thickness of 6.0 μm or more is preferred. The chemical vapor deposition method is more preferably a plasma CVD method. The plasma CVD method allows easy control of the deposition rate and is suitable as a deposition method of the SiO₂ film having a desired thickness, and moreover, this method is advantageous in that uniform and dense deposition is facilitated and in turn, the surface smoothness of the SiO₂ film is easily adjusted to a predetermined range.

[0065]

It is known that the SiO₂ film can be deposited also by a physical vapor deposition method such as vacuum deposition method or sputtering method, other than the plasma CVD method. However, as is known, in the vacuum deposition method, a

defect is readily occurred in the film and exposure of the defect to the polishing surface causes local deterioration in terms of surface roughness. In the sputtering method, a film having a smaller number of surface defects than in the vacuum deposition method may be obtained, but since the deposition rate is low, an SiO_2 film having a thickness of 6.0 μm or more can be hardly deposited with an efficiency worth the cost.

[0066]

In the case of depositing the SiO_2 film by the plasma CVD method, the SiO_2 film according to the present invention can be deposited by the reaction of an organosiloxane gas or a silane gas with an oxygen-containing gas. As the organosiloxane gas, for example, octamethyltrisiloxane or hexamethyldisiloxane can be used, and these may also be used in combination.

[0067]

As the silane gas, for example, SiH_4 , SiHCl_3 , SiH_2Cl_2 , SiH_3Cl , SiCl_4 , SiBr_4 , SiI_4 , SiF_4 , $\text{Si}(\text{OC}_2\text{H}_5)_4$ or $\text{Si}(\text{OCH}_3)_4$ can be used, and these may also be used in combination. Among these, $\text{Si}(\text{OC}_2\text{H}_5)_4$ or SiH_4 is particularly preferred.

[0068]

As the oxygen-containing gas, various conventional oxygen-containing gases can be used, and examples thereof include O_2 and N_2O . The oxygen-containing gas encompasses a mixed gas with N_2 , Ar or H_2 gas, etc. added as needed to deposit the SiO_2 film. Among those, an O_2 or N_2O gas is particularly preferred.

[0069]

[Aluminum Plate Temperature During Deposition of SiO_2 Film: 200°C or more and 370°C or less]

When the SiO_2 film is deposited in a high-temperature region of 200°C or more and 370°C or less, the SiO_2 film is shrunk together with the aluminum plate due to cooling after deposition, and a compressive stress of 450 MPa or more is obtained. When the SiO_2 film is deposited at a temperature where the temperature of the aluminum plate is less than 200°C, cracking or the like may be occurred in the SiO_2 film before the heating temperature of the aluminum substrate reaches 300°C, and heat resistance exceeding 300°C that is the heat resistance temperature of NiP plating cannot be imparted. On the other hand, when the temperature of the aluminum plate during deposition exceeds 370°C, the strength (tensile strength) of the aluminum plate

itself or a 0.2% yield strength is decreased to deteriorate the substrate properties required of a magnetic recording medium. In particular, when the aluminum plate temperature exceeds 370°C, the strength of the aluminum plate is decreased to 1/4 or less of the strength at room temperature, and deformation of the aluminum substrate or generation of unevenness on the aluminum substrate surface is caused during deposition or in the course of cooling after deposition. As a result, even when cooled to room temperature, a compressive stress of 450 MPa or more may not be obtained. Consequently, when the aluminum substrate is reheated, a tensile force may be generated in the SiO₂ film at a temperature lower than the deposition temperature, and the desired high-temperature heat resistance may not be obtained.

[0070]

From the standpoint of increasing the compressive stress, the temperature of the aluminum plate during the deposition of the SiO₂ film is preferably higher and is 200°C or more. If the temperature of the aluminum plate is too high, the properties of the aluminum plate, such as strength, are reduced. For this reason, the temperature of the aluminum plate is preferably 370°C or less, more preferably 350°C or less.

[0071]

As for the thickness of the SiO₂ film, the film may be deposited to have a thickness of 6.0 μm or more and 15.0 μm or less by raising the temperature of the aluminum plate to a range of 200°C or more and 370°C or less and controlling the deposition conditions in the temperature region above.

[0072]

As for other deposition conditions, conventional conditions may be employed.

[0073]

[Polishing Step]

In the SiO₂ film after the deposition above, the surface roughness is, for example, in terms of the centerline average roughness Ra specified in JIS B0601: 2001, preferably 0.5 nm or less, more preferably 0.3 nm or less.

[0074]

However, as described above, when the SiO₂ film is deposited by the plasma CVD method, the surface roughness on the aluminum plate surface is directly reflected as the surface roughness of the SiO₂ film. In order to reduce the load required for

polishing of the SiO₂ film, as described above, the smoothness on the aluminum plate surface is preferably increased in advance before the deposition of SiO₂ film.

[0075]

In the case of polishing the SiO₂ film after deposition, the surface roughness may be adjusted by polishing the surface of the SiO₂ film under conventional conditions. For the polishing of the SiO₂ film of the present invention, a method conventionally employed for polishing a glass plate or a device therefor may be used as it is. For example, wet polishing may be performed using a polishing pad and a polishing slurry. Examples of the polishing slurry include cerium oxide, zirconium oxide, and colloidal silica, which are usually used for the polishing of a glass substrate. Examples of the polishing pad include a suede-type polishing pad used for the polishing of a glass substrate. The polishing pressure may be, for example, 3 gf/cm² or more and 150 gf/cm² or less, and the sliding speed may be, for example, 30 cm/sec or more and 170 cm/sec or less. The polishing amount is not particularly limited, but in order to determine the compressive stress from the change in the polishing amount, a thickness of approximately 1 μm or more and 3 μm or less is preferably removed by polishing from the thickness of the SiO₂ film before polishing.

[0076]

[Use]

The aluminum substrate having deposited thereon an SiO₂ film of the present invention can be suitably used as a magnetic recording medium. In particular, the aluminum substrate where the SiO₂ film of the present invention increased in the heat resistance is deposited contributes to easing the constraints on the substrate temperature during the formation of a magnetic film. In producing a magnetic recording medium by using the aluminum substrate having deposited thereon an SiO₂ film of the present invention, a magnetic recording film, etc. are formed on the SiO₂ film surface of the aluminum substrate under conventional conditions, and a protective film and a lubricating film are further formed, if desired, whereby a magnetic recording medium can be produced.

EXAMPLES

[0077]

The present invention is described in greater detail below by referring to Examples, but the present invention is not limited to these Examples and can be implemented by appropriately adding changes as long as they comply with the gist described above and below, and these changes all are included in the technical scope of the present invention.

[0078]

(Test 1)

An aluminum plate having the composition shown in Table 1 below was processed into a hollow disk-shaped disk illustrated in FIG. 1 having an outer diameter of 65 mm and a thickness of 0.96 mm and having a center hole with an inner diameter of 20 mm. Both surfaces of the hollow disk-shaped disk were ground with a polyvinyl alcohol grinding stone to remove the altered layer resulting from rolling. In the grinding, a double-sided grinder, 16B, manufactured by Speed Fam Corporation was used and set such that the grinding is performed at a grinding pressure: 80 gf/cm² and a sliding speed: 80 cm/sec with a removal amount per surface: about 17 μm and the thickness of the hollow disk-shaped disk after the grinding becomes 0.925 mm. In Nos. 3 and 4, a disk prepared by using a 0.81 mm-thick aluminum plate and grinding it to a thickness of 0.770 mm was used. In all disks, the surface roughness after grinding was from 11 to 13 nm in terms of Ra.

[0079]

[Table 1]

Components of Aluminum Plate (mass%) *remainder being Al and unavoidable impurities				
Mg	Cr	Zr	Cu	Fe
5.9	0.5	0.02	0.01	0.05

[0080]

An SiO₂ film was deposited on the obtained hollow disk-shaped disk. Specifically, the temperature of the hollow disk-shaped disk during deposition was set to 330°C, and the SiO₂ film was deposited by the plasma CVD method under the following conditions. As for the deposition temperature, the correlation between the preset temperature of the deposition device and the temperature of the aluminum plate was determined using an aluminum plate to which a thermocouple is previously attached, and the temperature of the hollow disk-shaped disk during deposition was

controlled based on the correlation. After the deposition, the disk was left standing to cool to room temperature to obtain a hollow disk-shaped disk substrate having an SiO₂ film deposited on both surfaces thereof. This substrate is designated as Test Material No. 1.

[0081]

Substrates of Test Material Nos. 2 to 10 were manufactured in the same manner as Test Material No. 1. Test Material Nos. 9 and 10 are Comparative Examples.

[0082]

(Deposition Conditions of Plasma CVD Method)

Nos. 1 to 4:

Carrier gas: a mixed gas of tetraethylorthosilicate and oxygen

Gas ratio: TEOS/O₂ = 1:20

Flow rate: 700 sccm

Pressure: 50 Pa

RF Power: 400 W

[0083]

Nos. 5 to 10:

Carrier gas: monosilane, nitrogen and nitrous oxide

Gas ratio: SiH₄/N₂/N₂O = 1/9/7

Flow rate: 136 sccm

Pressure: 133 Pa

RF Power: 150 W

[0084]

(Thickness of SiO₂ Film)

The thickness of the SiO₂ film of each test material was measured using nanospec/AFT model 5100 manufactured by nanometrics Inc. and is shown in Table 2. In the Table, the value is a film thickness per one surface.

[0085]

(Variation in Warp)

Each test material was fixed on a flat-surface plate, and the displacement was measured using a stylus-based profilometer in the radius direction from a position 2

mm inward from the outer peripheral end of the hollow disk-shaped disk toward a position 2 mm outward from the inner peripheral end to determine the warp. At this time, as illustrated in FIG. 2, the displacement was measured in six directions from the outer peripheral side to the inner peripheral side of the hollow disk-shaped disk, and the average thereof is taken as the warp amount of each test material. The warp amount was measured before polishing the SiO₂ film and after polishing the SiO₂ film under the following conditions, and the value obtained by subtracting the warp amount after polishing from the warp amount before polishing was taken as the variation in warp. At the time of measurement of the warp amount after polishing, the warp amount was measured by fixing the test material on a flat-surface plate with the polishing surface up.

[0086]

(Polishing Amount of SiO₂ Film)

Only one surface of the SiO₂ film of each test material was polished using a desktop single-sided polishing machine manufactured by Speed Fam Corporation. A polishing pad (product name: RN-H Pad) for glass substrate manufactured by Rodel Nitta Company and a polishing slurry (product name: Compol 80) produced by Fujimi Inc. were used for the polishing. The polishing pressure and the sliding speed were 100 gf/cm² and 40 cm/sec, respectively, and the polishing amount was determined from the change in weight between before and after polishing, assuming that the density of the SiO₂ film is 2.2 g/cm³. The polishing amount of the SiO₂ film of each test material is shown in Table 2.

[0087]

(Hardness and Young's Modulus of SiO₂ Film)

The hardness and Young's modulus of the SiO₂ film of each test material were measured by a nanoindentation method and are shown in Table 2. Specifically, these were measured using a nanoindenter (Nano Indenter XP/DCM, manufactured by Agilent Technology). The measurement was performed under the conditions of an excitation frequency: 45 Hz, an amplitude of excitation vibration: 2 nm, a strain rate: 0.05/sec, and an indentation depth: 2,000 nm.

[0088]

(Compressive Stress)

As for the compressive stress, from the polishing amount and variation in warp of the SiO₂ film measured above, the compressive stress was calculated based on formula (11) and formula (12).

[0089]

(Heat Resistance Temperature)

In order to evaluate the heat resistance, the correlation between the preset temperature of the heating furnace and the temperature of the test material was determined by previously attaching a thermocouple to each test material, and the temperature of the heating furnace was set based on the correlation. The test material was inserted into a heating furnace heated to a temperature corresponding to the heat resistance evaluation temperature of the test material and after keeping the temperature for 15 minutes, the test material was taken out from the furnace and left standing to cool to room temperature.

[0090]

After standing to cool to room temperature, the surface property of the test material was observed. Specifically, the presence or absence of cracking in the SiO₂ film and the presence or absence of flaking of the SiO₂ film from the aluminum plate were examined with an eye under fluorescent lamp lighting and by an optical microscope under the following conditions.

[0091]

Observation Conditions of Optical Microscope

Magnification: 100 times

Measurement portion and number of measurements: 5 places per one surface

[0092]

Evaluation Criteria of Heat Resistance:

The heat resistance was evaluated by raising the heat resistance evaluation temperature in steps of 50°C from 250°C, and the maximum temperature not causing cracking or flaking is shown. For example, in No. 1, cracking or flaking was not observed in the SiO₂ film up to 500°C. Evaluation at a temperature of 500°C or more was not performed due to the constraints on the heat resistance of the aluminum plate.

[0093]

[Table 2]

No	Film Thickness μm	Plate Thickness mm	Deposition Temperature $^{\circ}\text{C}$	Hardness GPa	Young's Modulus GPa	Polishing Amount μm	Variation in Warp μm	Compressive Stress MPa	Heat Resistance Temperature $^{\circ}\text{C}$
1	10.1	0.925	330	9.9	72.9	1.83	38.4	789	500
2	10.0	0.925	260	9.0	67.7	1.62	33.7	795	500
3	10.1	0.770	260	9.1	67.6	2.05	59.7	765	500
4	9.6	0.770	210	8.8	66.5	2.19	52.5	630	450
5	9.2	0.925	300	8.3	67.4	1.75	26.8	581	400
6	6.3	0.925	250	8.4	67.4	1.71	26.8	590	400
7	10.5	0.925	250	8.8	69.2	1.75	22.2	480	350
8	6.1	0.925	200	8.0	67.1	1.68	20.7	466	350
9	10.5	0.925	150	8.5	67.2	1.58	16.9	405	300
10	6.5	0.925	150	8.4	67.4	1.62	16.2	380	300

[0094]

As shown in Table 2, in Nos. 1 to 8 where the compressive stress of the SiO₂ film having a thickness of 6.0 μm or more is 450 MPa or more, cracking or flaking was not observed in the SiO₂ film even when heated up to at least 350°C. In addition, as the compressive stress was increased, the heat-resistance temperature also became higher. The Young's modulus and hardness vary depending on the deposition temperature, reaction gas system and other production conditions, but all of Nos. 1 to 8 showed values close to those of fused silica and had sufficient properties as a film.

[0095]

On the other hand, in Nos. 9 and 10 where the compressive stress of the SiO₂ film is less than 450 MPa, cracking or flaking was observed in the SiO₂ film when heated over 300°C. It is considered that in Nos. 9 to 10, since the deposition temperature is low, the compressive stress is also decreased.

[0096]

(Test 2)

In order to examine the relationship between thickness and scratch resistance of the SiO₂ film, Test Material Nos. 2-1 to 2-5 differing in the film thickness were manufactured in the same manner as No. 2 of Test 1 except for changing the deposition conditions. As for the film thickness, the film was deposited to a predetermined thickness by controlling the deposition time.

Carrier gas: monosilane, nitrogen and nitrous oxide

Gas ratio: SiH₄/N₂/N₂O = 1/9/7

Flow rate: 136 sccm

Pressure: 133 Pa

RF Power: 150 W

Deposition temperature: 200°C

[0097]

Reference Example No. 1 is an aluminum plate on which an SiO₂ film is not deposited. Reference Example No. 2 is an Ni-P-plated aluminum substrate having a film thickness of 10 μm.

[0098]

(Scratch Resistance)

A stylus equipped with a 0.1 mm-radius diamond sphere, to which a load of 20 g or 40 g is applied, was slid on each test material by putting the tip thereof into contact with the SiO₂ film surface of the test material. The stylus was slid 15 mm at a constant sliding speed of 5 mm/sec. After the sliding, the depth of the sliding mark on the test material surface was measured by a non-contact optical roughness meter. FIG. 3 illustrates the results.

[0099]

As illustrated in FIG. 3, in Test Material No. 2-1 where an SiO₂ film having a thickness of 3.5 μm is deposited, the scratch resistance was equal at both loads of 20 g and 40 g to that of Reference Example No. 1 where an SiO₂ film is not deposited, and sufficient scratch resistance was not obtained.

[0100]

In Test Material No. 2-2 where an SiO₂ film having a thickness of 6.0 μm is deposited, the depth of the scratch could be reduced to 1/3 compared with Reference Example No. 1 at a load of 20 g, and scratch resistance substantially comparable to that of Reference Example No. 2 where an Ni-P plating is deposited was obtained at the same load.

[0101]

In Test Material No. 2-3 where an SiO₂ film having a thickness of 7.6 μm is deposited, the depth of the scratch could be reduced to 1/3 of Reference Example No. 1 also at a load of 40 g, and scratch resistance substantially comparable to that of Reference Example No. 2 was obtained at the same load.

[0102]

In Test Material Nos. 2-4 and 2-5 where an SiO₂ film is deposited as a thick film, scratch resistance surpassing that of Reference Example No. 2 was obtained at either load.

[0103]

While the present invention has been described in detail and with reference to specific embodiments thereof, it will be apparent to one skilled in the art that various changes and modifications can be made therein without departing from the spirit and scope of the present invention.

This application is based on Japanese Patent Application No. 2014-053730 filed on March 17, 2014, the contents of which are incorporated herein by way of reference.

INDUSTRIAL APPLICABILITY

[0104]

The aluminum substrate for a magnetic recording medium of the present invention, having formed thereon an SiO₂ film having a specific thickness and a specific compressive stress, is excellent in the scratch resistance as well as in the heat resistance, can be sufficiently applied to a heat-assisted magnetic recording system, and can realize high-density recording.

CLAIMS

1. An aluminum substrate for a magnetic recording medium, comprising an SiO₂ film deposited on both surfaces of the aluminum substrate, wherein
the SiO₂ film has a thickness of 6.0 μm or more and 15.0 μm or less and a compressive stress of 450 MPa or more and 1,000 MPa or less.
2. An aluminum substrate for a magnetic recording medium, comprising an SiO₂ film deposited on both surfaces of the aluminum substrate, the SiO₂ film having a thickness of 6.0 μm or more and 15.0 μm or less and a compressive stress of 450 MPa or more and 1,000 MPa or less, wherein
the SiO₂ film has been deposited by a vapor deposition method by heating a aluminum plate at 200°C or more and 370°C or less.
3. The aluminum substrate for a magnetic recording medium according to claim 2, wherein the vapor deposition method is a plasma CVD method.