

DESCRIPTION

TITLE OF THE INVENTION: ALUMINUM SUBSTRATE FOR MAGNETIC RECORDING MEDIUM

TECHNICAL FIELD

[0001]

The present invention relates to an aluminum substrate that is used as a substrate for a magnetic recording medium (magnetic disk), the aluminum substrate having deposited thereon a SiO_2 film suitable for forming a magnetic film (recording layer) under high temperatures.

BACKGROUND ART

[0002]

A magnetic recording medium is a medium that is highly versatile as an information recording medium. Properties required for the magnetic recording medium include superior hardness and scratch resistance, which are demanded. In a magnetic recording medium, for example, the magnetic head and the magnetic recording medium in some cases make contact with each other by an impact during fabrication or in use, and when a physical defect such as a scratch or depression occurs in the surface of the magnetic recording medium because of the contact or the like, the defect becomes a cause of a faulty recording medium. Therefore, magnetic recording mediums are required to have sufficient hardness and scratch resistance.

[0003]

In addition, the surfaces of magnetic recording mediums are required to be smooth. Recording and reading of information on and from the magnetic recording medium is performed via a magnetic head that moves above the recording medium, and the clearance (floating height-wise distance of the magnetic head) between the magnetic head and the magnetic recording medium is at most in the order of several nano-meters. For that reason, superior surface smoothness at the sub-nanometer level is desired for the magnetic recording medium in order to prevent contact with the magnetic head, or defective recording and reading.

[0004]

The substrate for magnetic recording medium includes an aluminum substrate, which is known; however, the aluminum substrate alone is insufficient in hardness and scratch resistance, and it is also difficult to achieve smoothness by polishing actions. Accordingly, a Ni-P plated aluminum substrate is used which has the surface of an aluminum substrate electrolessly Ni-P plated. The Ni-P plated film has high scratch resistance and hardness, achieving superior smoothness by polishing actions.

[0005]

After a rollingly fabricated, coil-shaped aluminum plate has been punched into a disk-shaped plate whose inner and outer circumferences have been turned and its main surface grounded, a Ni-P plated aluminum substrate is fabricated by being Ni-P plated by means of electroless plating, and further being polished and washed (Non-Patent Document 1).

[0006]

For example, in terms of a configuration of the structure of a

magnetic recording medium, the Ni-P plated aluminum substrate is formed with layers such as a soft magnetic backing layer and an intermediate layer (such as a crystal grain control layer and crystal orientation control layer), on which the magnetic film is deposited as a recording layer and further a surface protective layer (such as of hard carbon) is formed thereon.

[0007]

In recent years, increase in capacity of magnetic recording mediums has been advanced, and a next-generation magnetic recording medium is under development that dramatically enhances recording density. For example, if the density of magnetic recording media is attempted to advance its high density, then the size of a magnetic particle needs to be made minute; thus, the problem with thermal fluctuation is created in that the magnetic recording data partially disappears because of the ambient heat and therefore, the magnetic recording medium having improved coercivity of the magnetic film has been proposed. However, the enhancement of the coercivity makes it difficult to record data with the conventional head and thus, a heat assisted magnetic recording system that records data while heating the recording medium with a laser has been receiving attention. In this recording system, the coercivity is reduced of the heated portion of the magnetic film formed on the magnetic recording medium, thus enabling data recording. Further, since a non-heated part has high coercivity, thermal fluctuation can be eliminated.

[0008]

In the fabrication process of the magnetic recording medium suitable for such a thermally assisted recording system, the thermal history during

fabrication, such as deposition temperatures of the magnetic film is in some cases 300°C or more, and further 350°C or more. For an aluminum substrate formed with a Ni-P plate film, currently used for the general purpose, the thermal resistance of the aluminum substrate serving as a base is 370°C or more; however, the Ni-P plated film, when heated to 300°C or more, is crystallized to have magnetism and thus, the film is only able to support in the order of up to 300°C in actuality, and the withstand temperature of the substrate is a major constraint in the fabrication of a magnetic recording medium.

[0009]

With respect to such a problem, improving thermal resistance of the Ni-P plated film has been attempted by the addition of the third component (Patent Document 1); however, its thermal resistance is at most in the order of up to 320°C, and the effect of sufficiently improving thermal resistance has not been achieved.

[0010]

For this reason, a substrate film needs to be developed which substitutes for the current Ni-P plating, and is nonmagnetic and superior in terms of high hardness and scratch resistance and further, also thermal resistance. An amorphous SiO₂ film is focused on as a film that meets such conditions.

[0011]

For example, Patent Document 2 proposes a SiO₂ film based on the solgel method. However, when film deposition is made by the solgel method, the process of film deposition involves lost mass and great shrinkage in

volume, and necessary film thickness is difficult to achieve.

[0012]

Further, Patent Document 3 has proposed a technique in which a SiO₂ film of about 0.6 μm is deposited by a sputtering method. Although surface accuracy, hardness, wear resistance can be achieved, the film thickness of 0.6 μm is not sufficient to achieve the scratch resistance. When the SiO₂ film is thickened in order to improve the scratch resistance, a problem is created in that because there is a great difference in thermal expansion coefficient between the aluminum substrate and the SiO₂ film, the SiO₂ film tends to be easily cracked when exposed to the high temperature environment.

[0013]

Although a SiO₂ itself is nonmagnetic and has high temperature resistance, the problem, as described above, such as cracking is created when the SiO₂ is actually deposited on an aluminum substrate. As a result, SiO₂ films remain to be provided which have the practicality that causes no cracks or the like even when exposed to the high temperature environment.

[0014]

On the other hand, in terms of the thermal resistance of the aluminum substrate itself (base material) that is used for a magnetic recording medium, for example, a material such as a 5086 alloy (JIS H4000) has superior, high temperature thermal resistance at 300°C or more, and in recent years, an aluminum alloy substrate has also been proposed which can maintain surface smoothness even at about 500°C (Patent Document 4).

[0015]

Thus, if the SiO₂ film is achieved which corresponds to the aluminum substrate that is superior in terms of high temperature resistance, constraints can greatly be relaxed in terms of the application of the aluminum alloy substrate to a magnetic recording area, such as to the above described heat assisted recording system.

CITATION LIST

PATENT DOCUMENT

[0016]

Patent Document 1: JP 2012-195021 A

Patent Document 2: JP 2552682

Patent Document 3: Japanese Examined Patent Publication
1978-37202

Patent Document 4: JP 2012-99179 A

NON-PATENT DOCUMENT

[0017]

Non-Patent Document 1: Journal of The Japan Society for Abrasive
Technology (JSAT) Vol. 43, No. 11, Nov., 1999, pp. 475-479

SUMMARY OF THE INVENTION

[0018]

The present invention is made in view of the above described circumstances, and an object of the invention is to provide an aluminum substrate for a magnetic recording medium having superior thermal resistance, hardness and scratch resistance. In addition to these properties,

another object of the present invention is to provide an aluminum substrate for a magnetic recording medium which is capable of polishing for reducing the surface roughness as required, and is also superior in terms of surface smoothness after the polishing action.

[0019]

An aluminum substrate for magnetic recording medium according to the present invention that can solve the above problems is an aluminum substrate having deposited thereon a SiO_2 film of 6.0 μm or more in thickness, and has the point in that the SiO_2 film is the one deposited by a vapor phase deposition method with the aluminum substrate heated at 150°C to 370°C.

BRIEF DESCRIPTION OF DRAWINGS

[0020]

[Fig. 1] Fig. 1 is a graph showing a relationship between a substrate temperature during film deposition and a subtraction value of (thermal resistance evaluation temperature – substrate temperature during film deposition).

[Fig. 2] Fig. 2 is a graph showing a relationship between each of the various types of films (test materials 1 to 4 (SiO_2 film) and reference examples 1 and 2 (without SiO_2 film and the Ni-P plated film)) and the scratch depth.

[Fig. 3] Fig. 3 is a graph showing the surface roughness of the SiO_2 film before and after polishing of the SiO_2 film.

[Fig. 4] Fig. 4 is a graph showing changes in surface

roughness of the SiO₂ film after deposition of the SiO₂ film and the roughness of the aluminum substrate surface before deposition of the SiO₂ film.

DESCRIPTION OF EMBODIMENT

[0021]

An embodiment according to the present invention will be described hereinafter. In the present embodiment, the term "substrate temperature during film deposition" refers to the temperature of an aluminum substrate itself when a SiO₂ film is deposited, and to the temperature of the substrate to be measured with a thermocouple installed on the substrate. In the present specification, the term "substrate temperature during film deposition" is in some cases referred to simply as "film deposition temperature" or alternatively, as "substrate temperature."

[0022]

Further, the term "substrate temperature during heating" refers to a temperature of the substrate itself when exposed to the high temperature environment in the process of fabrication of the magnetic recording medium, such as of forming a magnetic film and a surface protective layer, and the temperature is a temperature of the substrate to be measured with a thermocouple in a fashion similar to the above. In the present specification, the term "substrate temperature during heating" is in some cases referred to simply as "heating temperature" or alternatively, as "thermal resistance evaluation temperature."

[0023]

Further, the term "heating temperature difference" refers to a temperature difference between the above described "substrate temperature during heating" and "substrate temperature during film deposition."

[0024]

It should be noted that since in the present embodiment, the temperature of the substrate is measured, set-up temperatures of the device, atmosphere, etc., when depositing the SiO₂ film, magnetic film, etc., in some cases do not agree with a temperature of the substrate (substrate temperature during heating). For example, in the examples according to the present invention, in order to evaluate the thermal resistance of the substrate having the SiO₂ film deposited thereon, the relationship between the temperature within the heating furnace and the temperature of the substrate is examined with a thermocouple attached in advance to the substrate, and the temperature of the heating furnace is set such that the substrate temperature is the one that simulates the thermal history in the fabrication process; therefore, in some cases the temperature of the heating furnace is not in agreement with the temperature of the substrate.

[0025]

The inventors have conducted extensive studies about a film that has sufficient hardness and scratch resistance to the extent that the conventional Ni-P plated film can be replaced, and that has superior thermal resistance which surpasses the Ni-P plating film.

[0026]

In general, the thermal expansion coefficient of aluminum (including pure aluminum or aluminum alloys) is around $24 \times 10^{-6}/K$, and is known to

linearly expand about 1% in a temperature increase of 400°C. On the other hand, the thermal expansion coefficient of SiO₂ is generally known to be the one in the order of 1×10^{-7} to $1 \times 10^{-6}/K$; the linear expansion of SiO₂ is in the order of a few percent of the linear expansion of the aluminum.

[0027]

The inventors investigated the aluminum substrate having a SiO₂ film deposited thereon under various conditions.

[0028]

The aluminum substrate temperature, when the SiO₂ film was deposited, was first set to about the room temperature (25°C) to deposit the SiO₂ film having a thickness of 3.5 μm, and the aluminum substrate was next placed into an electric furnace for being heated, and then it became apparent that a problem was created in that when the heating temperature (substrate temperature during heating) reached about 250°C, cracks occurred in the SiO₂ film, the SiO₂ film was separated from the aluminum substrate, or a similar action occurred.

[0029]

On the other hand, when the substrate temperature during deposition of the SiO₂ film was increased to 150°C or more, cracking or peeling was not recognized in the SiO₂ film (Nos. 3 to 24 in Table 1) even if heating temperature (thermal resistance evaluation temperature) of the substrate reached 300°C or more. This fact shows that in order to ensure thermal resistance (substrate temperature during heating) of 300°C or more, it is adequate if the substrate temperature during film deposition is set to at least 150°C or more.

[0030]

When the SiO_2 film is deposited at a high temperature in this way, a reason showing that superior high temperature resistance at a high temperature of 300°C or more (thermal resistance evaluation temperature) is thought to be as follows.

[0031]

The SiO_2 , which is affected by its shape and size, generally has properties such that it tends to easily break against the tensile force, but to be hard to fracture against compressive force. Therefore, when the SiO_2 film is deposited with the aluminum substrate heated as described above, the SiO_2 film, when cooled from the film deposition temperature to room temperature, is in a state of being compressed. Thus, a load (compression force) is created by a differential contraction between the SiO_2 film and the aluminum substrate; however, the SiO_2 film is superior in terms of durability for a compression force and thus, cracking or peeling of the SiO_2 film is thought not to occur.

[0032]

On the other hand, when heating the aluminum substrate having deposited the SiO_2 film on which compressive force is exerted at room temperature in this way, the SiO_2 film is stretched by the aluminum substrate being thermally expanded; however, the compressive force has been acting at room temperature and accordingly, the force acts in the direction of the compression state being relaxed up to the deposition temperature of the SiO_2 film and thus, the tensile forces acting on the SiO_2 film are actually relaxed. As a result, it is thought that cracking or peeling

of the SiO₂ film is hard to occur and superior thermal resistance is provided.

[0033]

In other words, the thermal expansion of the SiO₂ film is mainly controlled by the difference between the heating temperature and the film deposition temperature and thus, when the SiO₂ film is deposited at high temperature, and even when reheated, the tensile force does not substantially act on the film from room temperature to the film deposition temperature, and when the substrate is heated above a film deposition temperature, the tensile force acts on the SiO₂ film in the range from the film deposition temperature up to a heating temperature. Therefore, when the deposition temperature of SiO₂ film is high, the difference between the deposition temperature of SiO₂ film and the heating temperature after the deposition of SiO₂ film creates tensile force and thus, it is thought that cracking or peeling of the SiO₂ film resulting from the difference of thermal expansion coefficient is hard to occur, as compared with the case in which the SiO₂ film is deposited at room temperature.

[0034]

The hardness of the SiO₂ film at room temperature also tended to be higher with increasing substrate temperature during film deposition. The hardness of the SiO₂ film, when the substrate temperature during film deposition was set to, for example, 150°C, was 8.0 GPa, but as the substrate temperature increased, the hardness became 8.4 GPa (200°C), 8.8 GPa (250°C) (Nos. 13 to 18). The same holds true for a different film thickness. When the film thickness was set to be, for example, 10.5 μm (Nos. 19 to 24), in the same way, the hardness tended to be higher (8.5 GPa to 8.8 GPa to 9.2

GPa) with increasing temperature (200°C to 250°C to 300°C).

[0035]

Thus, it was found that in order to impart sufficient hardness, it was adequate if the deposition temperature of SiO₂ film was increased.

[0036]

It was further found that if the thickness of the SiO₂ film was thin, then the function (scratch resistance) serving as a protective film for the surface of the aluminum substrate was insufficient and a certain level of film thickness was required. In other words, in examples (Nos. 1 to 12) of a film thickness of 6 μm or less, any one had poor scratch resistance; however, the examples of a film thickness of more than 6 μm had scratch resistance at a satisfactory level (from No. 13 onward) and in particular, the examples (Nos. 19 to 24) of a film thickness of above 10 μm had more superior scratch resistance.

[0037]

The present invention is made based on the above findings, and has the point in that it pertains to an aluminum substrate having deposited thereon a SiO₂ film of a thickness of 6.0 μm or more, the SiO₂ film being deposited, with the aluminum substrate heated at 150°C to 370°C, by vapor phase deposition method.

[0038]

The configuration of aluminum substrate of the magnetic recording medium according to the present embodiment will be hereinafter described in detail.

[0039]

[Film thickness of the SiO₂ film: 6.0 μm or more]

When the film thickness of the SiO₂ film formed on an aluminum substrate is thin, its scratch resistance is insufficient even if its hardness is high, and defects tend to easily occur in the magnetic recording medium. On the other hand, if a SiO₂ film having a film thickness of 6.0 μm or more is formed in the substrate temperature range during the predetermined film deposition, and even if the magnetic recording medium surface is subjected to an impact during fabrication or in use, then sufficient scratch resistance can be imparted to the film to the extent such that the physical defects such as scratches and dents can be restrained. Therefore, the thickness of the SiO₂ film needs to be more than 6.0 μm, preferably 9.0 μm or more, and more preferably 10.0 μm or more. On the other hand, from the viewpoint of scratch resistance, the upper limit of the film thickness is not particularly restricted; however, when the film thickness of the SiO₂ film is too thick, the proof stress against a tensile stress resulting from a thermal expansion, as will be described later, is lowered and thus, preferably the thickness of the film is 15.0 μm or less.

[0040]

It should be noted that in situations where the SiO₂ film is polished for attainment of the desired surface smoothness, the film thickness of the SiO₂ film to be deposited is preferably determined in consideration of the amount of polishing actions, and the film thickness after the polishing actions falls in the above described range.

[0041]

[Aluminum substrate temperature during film deposition of SiO₂

film: 150°C to 370°C]

When the SiO₂ film is deposited at a temperature in which the temperature of the aluminum substrate is lower than 150°C, thermal resistance of greater than 300°C, which is a withstand temperature of the Ni-P plating, cannot be imparted because in some cases cracks or the like occurs in the SiO₂ film before the heating temperature of the substrate reaches 300°C. On the other hand, when the temperature of the aluminum substrate during film deposition exceeds 370°C, substrate properties required for the magnetic recording medium are poor because the strength of the aluminum substrate itself (tensile strength) and the 0.2 percent proof stress lowers. In particular, when the substrate temperature exceeds 370°C, the strength of an aluminum substrate is lowered to 1/4 or less of its strength at room temperature, resulting in deformation of the aluminum substrate in the cooling process during or after film deposition, and in occurrence of irregularities on the substrate surface. As a result, in some cases sufficient compressive force, even when cooled to room temperature, is not exerted on the SiO₂ film. For that reason, as the substrate is reheated, the tensile force is produced in the SiO₂ film at a temperature lower than the film deposition temperature, and the desired high temperature resistance cannot in some cases be obtained.

[0042]

From the viewpoint of enhancing thermal resistance, a higher aluminum substrate temperature is appropriate during deposition of the SiO₂ film and thus, the temperature of the aluminum substrate is 150°C or more, preferably 200°C or more. In addition, when the temperature of the

aluminum substrate is raised too high, the properties such as the strength of aluminum substrate lower as described above; thus, the temperature is 370°C or less, preferably 350°C or less.

[0043]

With the temperature of the aluminum substrate raised to 150°C to 370°C, a SiO₂ film is deposited by vapor phase deposition method at the temperature range, whereby, as described above, the temperature at which the tensile force starts to act can be increased—the tensile force being caused by the thermal expansion resulting from the SiO₂ film being heated—and therefore cracking and peeling of the SiO₂ film can be prevented.

[0044]

Further, in the present embodiment, it is also a preferable aspect that the deposition temperature of SiO₂ film is determined in consideration of the film thickness of the SiO₂ film and the required withstand temperature (temperature during heating). The inventors studied the relationship between the thickness of the SiO₂ film, the difference of heating temperature ([substrate temperature during heating] – [substrate temperature during film deposition]) and the thermal resistance. As a result, it was found that as the film thickness of the SiO₂ film increased and the heating temperature difference increased, the proof stress against the tensile force lowered—the tensile force resulting from the difference in thermal expansion between the aluminum substrate and the SiO₂ film, the difference being produced by the difference in temperature of heating the SiO₂ film—and cracking or peeling of the SiO₂ film tended to occur (Table 1 and Fig. 1). Thus, it is desirable that fabrication conditions be

appropriately controlled in order to restrain the occurrence of defects such as cracks in relation to the above film deposition temperature and tensile stress.

[0045]

For instance, in the example of the film thickness 6.1 μm (Nos. 13 to 18 in Table 1), when the substrate temperature during film deposition ("substrate temperature during film deposition " in Table 1) was any one of 150°C, 200°C and 250°C, superior thermal resistance ("thermal resistance evaluation" in Table 1) was obtained (Nos. 13, 15 and 17) if the heating temperature difference ("thermal resistance evaluation temperature - substrate temperature during film deposition" in Table 1) was in the range of 150°C to 175°C; however, the example of a heating temperature difference of 200°C had inferior thermal resistance (Nos. 14, 16 and 18). On the other hand, in the example of the film thickness 10.5 μm (Nos. 19 to 24 in Table 1), when the substrate temperature during film deposition was any one of 200°C, 250°C and 300°C, superior thermal resistance was obtained (Nos. 19, 21 and 23) if the heating temperature difference was in the range of 100 to 125°C; however, the example of a heating temperature difference of 150°C had inferior thermal resistance (Nos. 20, 22 and 24). Of these examples, when comparing No. 15 (film thickness: 6.1 μm) whose substrate temperature during film deposition was 200°C with No. 19 (film thickness: 10.5 μm), No. 15 exhibited proper thermal resistance even at a heating temperature difference of 175°C, while the temperature at which No. 19 exhibited proper thermal resistance was up to 125°C. Therefore, No. 15 had proper thermal resistance up to 375°C of the substrate temperature during heating

("thermal resistance evaluation temperature" in Table 1), while No. 19 had the thermal resistance up to 325°C thereof. In order to exhibit the thermal resistance at the substrate temperature (375°C) during heating equivalent to No. 15, the substrate temperature during film deposition needs to be increased up to 250°C (No. 21).

[0046]

This tendency is as summarized in Fig. 1. In order to set the substrate temperature during heating having thermal resistance, for example, at 350°C or more (the right side of the "350°C line" in Fig. 1), it is adequate for the film thickness of SiO₂ film of 6.1 μm if the substrate temperature during the film deposition is set at 200°C or more; however, for the film thickness of 10.5 μm, the temperature is 250°C or more, and as the film thickness increases, there is a tendency of the substrate temperature during the film deposition to be increased and of the heating temperature difference to be reduced.

[0047]

Therefore, in order to exhibit thermal resistance at high temperatures, the difference is preferably reduced between the substrate temperatures during heating and during film deposition by increasing the substrate temperature during film deposition with increasing film thickness of the SiO₂ film.

[0048]

It should be note that such a relationship between the film thickness and the heating temperature difference indicates substantially the same tendency for the same film thickness, regardless of the substrate

temperature during heating as described above and thus, it is adequate if the substrate temperature during heating is increased so that the thermal resistance is obtained at a desirable substrate temperature during heating.

[0049]

[Hardness of SiO₂ film: preferably 4.0 GPa or more]

The hardness of the SiO₂ film, while being not particularly limited, is preferably high from the viewpoint of enhancing the durability of the aluminum substrate for physical impact or the like. In addition, in order to enhance scratch resistance, the thickness of the film is preferably increased with sufficient hardness secured. The hardness of the SiO₂ film is preferably 4.0 GPa or more, and more preferably 7.0 GPa or more.

[0050]

It should be noted that there is a tendency of the hardness to increase with increasing substrate temperature during deposition of the SiO₂ film and thus, it is adequate if the substrate temperature is set so that desired hardness can be obtained in the range (150°C to 370°C) of the substrate temperature during the above film deposition.

[0051]

[Deposition of SiO₂ film: vapor phase deposition method]

Further, the SiO₂ film according to the present embodiment is the one deposited by the vapor phase deposition method. The vapor phase deposition method is desirable because of being easy to control of the film thickness and being easy to make uniform and dense film deposition. The vapor phase deposition method refers to a physical vapor phase deposition method (PVD), such as sputtering and vacuum evaporation method and a

chemical vapor phase deposition method (CVD) such as plasma CVD. Of these methods, the chemical vapor phase deposition method is preferable from the fact that the desired film thickness of 6 μm or more is easy to deposit. In addition, of the chemical vapor phase deposition methods, a plasma CVD method is particularly more preferable. The plasma CVD method, because of being easy to control the film deposition rate, is suitable as a method of depositing the SiO_2 film having a desired film thickness, and is preferable because of uniform and dense film deposition being easy and thus, of being easy to adjust surface smoothness of the SiO_2 film to the predetermined range.

[0052]

The reason that the plasma CVD method is preferable with respect to in particular the surface smoothness is as follows. In other words, Fig. 4 is a graph showing a general tendency of the roughness of the surface of the aluminum substrate before depositing the SiO_2 film, and that of the roughness of the SiO_2 film surface after depositing the SiO_2 film by the plasma CVD method. In Fig. 4, the "tracer method" represents the results of measurement of multiple samples using a Taylor/Hobson-made Intra; the "AMF1" represents a result of measurement using an Nanoscience Instruments-made Nanosurf EasyScan (viewing angle $10\mu\text{m}$) and the "AMF2," that of measurement using an Nanoscience Instruments-made Nanosurf EasyScan (viewing angle $2\mu\text{m}$). From the fact that any measurement method indicates substantially the equivalent surface roughness (Ra center line surface roughness (nm)) before and after deposition of the SiO_2 film, it is thought, when the SiO_2 film is deposited by a

plasma CVD method, that the surface roughness of the SiO_2 film deposited substantially directly reflects the roughness of the aluminum substrate surface before film deposition.

[0053]

However, as shown in the examples to be described later, the SiO_2 film deposited by the plasma CVD method is easily polished by a known surface polishing process of the glass substrate, and the surface roughness can be reduced to a desired value, and superior smoothness is easily obtained (Fig. 3).

[0054]

It should be noted that when a SiO_2 film is deposited by a sputtering method, the film deposition using a reactive sputtering method—in which with Si used as a target, carrier gas made by adding O_2 to Ar is sputtered using RF plasma or pulsed DC discharge plasma—means that the film deposition rate is fast and practical.

[0055]

Further, in the case of depositing the SiO_2 film by vacuum evaporation method, a mixed powder of SiO_2 and Si is heated in a furnace, and is vaporized as SiO whose sublimation temperature is low, and if a minute amount of the O_2 is applied to the neighborhood of the substrate surface, then a SiO_2 film can be formed.

[0056]

A method of manufacturing an aluminum substrate for a magnetic recording medium according to the present embodiment will be described hereinafter.

[0057]

The aluminum substrate is first prepared. An aluminum substrate used in the present embodiment (base material) is not limited particularly, but is preferably equal to or greater than the 5086 alloy in terms of the tensile strength and 0.2 percent proof stress at room temperature. The thickness of the aluminum substrate is not particularly limited, and various thicknesses can be used, but it is adequate if the thickness is appropriately determined so as to be finished to a predetermined thickness usually required as a magnetic recording medium. It is adequate if the aluminum substrate with a thickness of 1.270 mm or 1.753 mm is used for the aluminum substrate for the magnetic recording medium with a diameter of 95 mm, for example; in addition, it is adequate if an aluminum substrate with a thickness of 0.635 mm or 0.800 mm is used for the aluminum substrate for the magnetic recording medium with a diameter of 65 mm.

[0058]

The aluminum substrate is punched into a desired shape, and it is recommended to subject the substrate to an annealing process. By being subjected to the annealing process, the distortion due to the process can be eliminated and further, the degree of flatness can be improved.

[0059]

Since a surface alteration layer resulting from rolling or the like has been formed on the above described aluminum substrate surface, preferably, the surface alteration layer is removed by a processing method such as facing or grinding process using a lathe, or in combination of both, to keep the surface of the aluminum substrate smoothed. In addition, if the surface

roughness of the aluminum substrate is too great, there is a possibility that desired surface roughness (surface smoothness) is not obtained even by polishing the SiO₂ film and thus, it is preferable to keep the surface smoothed.

[0060]

The above described processing method is not particularly limited, and in general could employ wet grinding using a PVA grindstone, and facing using a diamond cutting tool. Further, after the facing, the wet grinding using the PVA grindstone may be performed.

[0061]

The surface roughness of the above aluminum substrate is preferably 20 nm or less, more preferably 12 nm or less, in the center line average roughness Ra defined in, for example, JIS B0601 (2001).

[0062]

[Deposition of SiO₂ film]

In the present embodiment, a SiO₂ film of 6.0 μm or more is deposited on the aluminum substrate heated at 150°C to 370°C by vapor phase deposition method.

[0063]

For example, when a SiO₂ film is deposited by a chemical vapor phase deposition method desirable as a vapor phase deposition method, the SiO₂ film can be deposited on the surface of the aluminum substrate heated to a predetermined temperature, by using an organosiloxane gas (compound having a Si-O-Si bond in molecular framework) or a silane gas, and an oxygen-containing gas.

[0064]

In order to deposit good film quality, namely, dense, hard, and smooth SiO_2 film, preferably, Si contained in the organosiloxane gas is completely converted to SiO_2 . To that end, when depositing the SiO_2 film, it is recommended to use oxygen-containing gas in an amount of 1.2 times or more the stoichiometric amount of oxygen gas that is needed for conversion of Si contained in the above described organosiloxane gas to SiO_2 . In theory, if the oxygen-containing gas is used in the stoichiometric amount required for the conversion of the Si contained in the organic siloxane gas to SiO_2 , the Si should completely be converted to SiO_2 . In practice, however, reaction loss, byproducts and the like affect the conversion. Therefore, to completely convert Si to the SiO_2 , it is desirable to use oxygen gas of an excess amount (specifically, 1.2 times or more) for the stoichiometric amount. In the present embodiment, it is recommended to control the flow rate of oxygen-containing gas so that the ratio of oxygen gas flow rate during film deposition falls in the above described range.

[0065]

The above organosiloxane includes, for example, hexamethyldisiloxane (HMDSO) and octamethyltrisiloxane, which can be used. And they may be used in combination. Considering suitable vapor pressure, safety, ease of availability, film deposition rate, and hardness of the SiO_2 film to be deposited, it is preferable to use HMDSO.

[0066]

The above described silane gas includes gas such as SiH_4 , SiHCl_3 , SiH_2Cl_2 , SiH_3Cl , SiCl_4 , SiBr_4 , SiI_4 , SiF_4 , or $\text{Si}(\text{OC}_2\text{H}_5)_2$, which can be used.

Such a gas may be employed in combination. Among them, particularly preferred is SiH_4 .

[0067]

Further, Gas such as O_2 and N_2O are exemplified as the above described oxygen-containing gas. It should be noted that the point of this is that the oxygen-containing gas includes a gas mixed with H_2 gas, which is to be added as required to form the SiO_2 film. Of these, particularly preferred is a mixed gas of O_2 or N_2O gas.

[0068]

[Regarding polishing process]

The surface roughness of the above described SiO_2 film after deposition is preferably, for example, 0.5 nm or less, more preferably 0.3 nm or less, in the center line average roughness R_a defined in JIS B0601 (2001).

[0069]

However, in situations where the SiO_2 film is deposited by plasma CVD method, as described above, surface roughness of the SiO_2 film directly reflects the surface roughness of the aluminum substrate surface. For this reason, the surface smoothness of the SiO_2 film is high. In order to reduce a burden required for the polishing of the SiO_2 film, it is preferable that the smoothness of the aluminum substrate surface be increased in advance before deposition of the SiO_2 film, as described above.

[0070]

Further, when polishing the SiO_2 film after deposition, it is adequate if the surface of SiO_2 film is polished under the known conditions, to achieve the above desired smoothness (the above described surface roughness). The

polishing of the SiO_2 film according to the embodiment can directly employ a conventionally used method of polishing a glass plate, and an apparatus therefor. For example, it is adequate if wet polishing is performed using a polishing pad and polishing slurry. It is adequate if the polishing pressure is set to, for example, 40 to 150 gf/cm², and the sliding speed is set to, for example, 40 to 160 cm/sec.

[0071]

[Applications]

An aluminum substrate having a SiO_2 film deposited thereon according to the present embodiment can suitably be used as a magnetic recording medium. In particular, the aluminum substrate having the SiO_2 film having thermal resistance improved according to the present embodiment deposited thereon contributes to the constraint relaxation of the substrate temperature during formation of the magnetic film. In the fabrication of a magnetic recording medium using an aluminum substrate having a SiO_2 film according to the present embodiment deposited thereon, a magnetic recording film and the like is formed under the known conditions on the SiO_2 film surface of the aluminum substrate and further, a protective film and lubricating film is formed as required, and then the magnetic recording medium can be fabricated.

[0072]

The present specification discloses techniques of various aspects, as described above, and the above described problems can be solved in the following aspects. However, the present invention is not limited to the following solution. It should of course be understood that the entire

contents described in the present specification can be considered.

[0073]

The aluminum substrate for magnetic recording medium, which is one aspect of the present invention, is an aluminum substrate having a SiO₂ film with a thickness of 6.0μm or more deposited thereon, and is characterized in that the SiO₂ film is deposited by vapor phase deposition method with the aluminum substrate heated at 150°C to 370°C.

[0074]

With such a configuration, the SiO₂ film having a predetermined film thickness is deposited on an aluminum substrate heated to a predetermined temperature range and thus, it is nonmagnetic and has superior properties in thermal resistance (preferably 300°C or more, more preferably 350°C or more, further more preferably 400°C or more), hardness (preferably 4.0 GPa or more, more preferably 7.0 GPa or more), and scratch resistance (preferably equivalent or better Ni-P plating). Further, a technique of polishing a conventional glass substrate can be applied, as polishing means after film deposition, to the SiO₂ film according to the present invention, and the aluminum substrate for magnetic recording medium having superior surface smoothness can be provided by the polishing action.

[0075]

Thus, the aluminum substrate having the SiO₂ film deposited thereon according to the present invention is suitable as a magnetic recording medium, and can greatly relax constraints of the use of the aluminum alloy substrate in a magnetic recording field, such as in a thermally assisted recording system.

[0076]

Further, in the aluminum substrate for the magnetic recording medium according to the present invention, the gas phase deposition method is preferably a plasma CVD method. This is because the SiO₂ film deposited by the plasma CVD method is easy to polish by the known method of polishing the surface of glass substrate, and the surface roughness can be reduced to a desired value and superior smoothness can be easily achieved.

[0077]

The present embodiment will be described below more specifically by way of examples. The present invention is not limited to the following examples, but appropriate modifications within a range conformable to the gist described hereinbefore and hereinafter can of course be made, and any of them is included in the technical scope of the present invention.

Examples

[0078]

Experiment 1

In Experiment 1, the relationship between the deposition temperature of the SiO₂ film and the characteristics of the SiO₂ film was examined.

[0079]

An aluminum substrate (aluminum alloy (4.2 mass% Mg -balance: Al and unavoidable impurities), size: disc-shaped disk of outer diameter 65 mm, inner diameter 20 mm, and thickness about 0.84 mm), was ground with a PVA grindstone, and its alteration layer resulting from rolling was

removed. Using a Speed Fam-made 16B double-sided machine, the grinding process was carried out at a grinding pressure of 80 gf/cm² and a sliding speed of 80 cm/s, and with a removal amount per face set to approximately 20 μm, the thickness of the aluminum substrate after the polishing action was set to be 0.800 mm. When the surface roughness of the aluminum substrate after grinding was measured by the tracer method, it was found that Ra = 12 nm. After that, the SiO₂ film having a film thickness of 3.5 μm to 10.5 μm was deposited by the plasma CVD method under the following conditions, as well as the substrate temperature during film deposition being varied between 80°C and 350°C ("the substrate temperature during film deposition (°C)" in Table 1). At this time, a correlation was found between the set-up temperature of the film deposition apparatus and the substrate temperature using an aluminum substrate with a thermocouple attached in advance, and in accordance with this correlation, the substrate temperature during film deposition was controlled to be the predetermined temperature. After the film deposition, by being cooled to room temperature, a test material was obtained where the SiO₂ film was deposited on the surface of the aluminum substrate.

[0080]

(Film deposition conditions of plasma CVD method)

Carrier gas: gas mixture of mono silane and nitrogen, and nitrous oxide

Gas ratio: SiH₄/N₂ = 1/9

Flow rate: 80 sccm

N₂O flow rate: 56 sccm

Pressure: 133 Pa

RF Power: 150 W

[0081]

(Surface properties of SiO₂ film)

Surface properties of each test material obtained were examined at room temperature. It was visually verified whether there were cracks in the SiO₂ film of each test material and separation between the film and the substrate. As a result, there was no test material that created cracks or peeling, and the surface properties of all the test materials were satisfactory.

[0082]

(Film thickness of SiO₂ film)

The film thickness of the SiO₂ film of each test material was measured using a Nanometrics-made nanospec/AFT model 5100.

[0083]

(Hardness of SiO₂ film)

The hardness of the SiO₂ film of each test material was measured using a nanoindentation method. Specifically, the hardness was measured using Nano Indenter (Agilent Technologies-made Nano Indenter XP/DCM). The measurement was made based on excitation frequency: 45 Hz, excitation vibration amplitude: 2 nm, strain rate: 0.05/sec, and indentation depth: 2000 nm.

[0084]

(Thermal resistance evaluation)

In order to evaluate the thermal resistance, the correlation between the set-up temperature of the furnace and the substrate temperature was examined using a substrate with a thermocouple attached in advance, and

the temperature of the furnace was set in accordance with the correlation. A test material was placed into a heating furnace heated to a temperature corresponding to the thermal resistance evaluation temperature (substrate temperature during heating) shown in Table 1 and was left as it is for 30 minutes, and thereafter, the test material was taken out of the furnace and left cooled until its temperature reached to room temperature (25°C).

[0085]

After cooling, the surface properties of the test material were observed at room temperature. Specifically, visual observation was made under fluorescent lighting, and the presence or absence of cracks of the SiO₂ film and the presence or absence of separation between the SiO₂ film and the aluminum substrate were examined under an optical microscope (magnification: x 50 and x 200, any five points on each of the substrate periphery, center, outer peripheral portion per one side), and then the results were evaluated according to the following criteria ("evaluation of thermal resistance" in Table 1).

○: Cracking or peeling was not recognized in SiO₂ film.

○ Note 1: peeling or cracking was not recognized in the SiO₂ film, but an example of the withstand temperature being less than 300°C.

X Note 2: deformation occurred on aluminum substrate.

X: Cracking or peeling was observed in the SiO₂ film.

[0086]

The thermal resistance evaluation temperature was raised by a few dozens °C at a time from 250°C to evaluate the thermal resistance, the example of "○" evaluation indicates the maximum temperature at which no

cracking or peeling was observed, and that of "X" evaluation indicates the temperature at which peeling or cracking was observed. For example, No. 13 and No. 14 show that the thermal resistance evaluation of up to 325°C was "○" (No. 13), but it was "X" (No. 14) at 350°C, at which the temperature further increased 25°C.

[0087]

(Scratch resistance evaluation)

The tip (diamond sphere having a radius of 0.1 mm) of the stylus to which a load of 10 g or 50 g was applied was caused to make contact with, and slide on, the surface of test material (film deposition surface). The sliding speed was set to a constant rate (5 mm/s), and a sliding distance to 15 mm. After sliding, the depth of the sliding mark on the surface of test material was measured with a noncontact optical roughness meter device, and evaluated by the following criteria.

[0088]

○: Under any of a 10 g and a 50 g load, scratch depth is equivalent to or less than that of the Ni-P plating.

△: Under the 10 g load, scratch depth is equivalent to or less than that of the Ni-P plating, but under the 50 g load, it is deeper than that of Ni-P plating.

X: Also under the 10 g load, scratches are deeper than Ni-P plating.

—: No evaluation of scratch resistance was made because sufficient thermal resistance (evaluation of thermal resistance "X") could not be achieved.

[0089]

The above test results are shown in Table 1.

[0090]

Table 1

No	Film thickness (μm)	Substrate temperature during film deposition (°C)	Hardness (GPa)	Thermal resistance evaluation temperature (°C)	Thermal resistance temperature during film deposition (°C)	Thermal resistance evaluation	Scratch resistance evaluation
1	3.5	80	7.5	275	195	○ Note 1	X
2				300	220	X	—
3				375	225	○	X
4				400	250	X	—
5		200	8.3	400	200	○	X
6				450	250	X	—
7				450	200	○	X
8				500	250	X Note 2	—
9		300	8.8	460	160	○	X
10				500	200	X Note 2	—
11				460	110	○	X
12				500	150	X Note 2	—
13	6.1	150	8	325	175	○	Δ
14				350	200	X	—
15				375	175	○	Δ
16		200	8.4	400	200	X	—
17				400	150	○	Δ
18				450	200	X	—
19	10.5	200	8.5	325	125	○	○
20				350	150	X	—
21				375	125	○	○
22		250	8.8	400	150	X	—
23				400	100	○	○
24				450	150	X	—

[0091]

Based also on the example of "○" evaluation in Table 1, the relationship between the substrate temperature during film deposition and [the thermal resistance evaluation temperature – the substrate temperature during film deposition] was shown in Fig. 1 for each film thickness of the SiO₂ film. In Fig. 1, diagonal lines ("300°C line," "350°C line" and "substrate deformation") correspond to the withstand temperatures.

[0092]

Nos. 13 to 24 satisfying the film thickness and the film deposition conditions according to the present embodiment were superior in terms of thermal resistance (thermal resistance evaluation temperature: 300°C or more), scratch resistance (Δ or more), and hardness (4.0 GPa or more). Particularly, in Nos. 19 to 24 in which the film thickness of the SiO₂ film was set at 10 μ m or more, superior scratch resistance was obtained as compared with Nos. 13 to 18 in which the film thickness of the SiO₂ film was set at film thickness 6.1 μ m.

[0093]

On the other hand, in the examples which do not satisfy the requirements of the present invention, the desired properties could not be obtained.

[0094]

When the substrate temperature during film deposition (80°C) was low (Nos. 1 and 2), thermal resistance at 275°C was obtained (No. 1), but high temperature resistance at 300°C or more could not be obtained (No. 2).

[0095]

In addition, although when the film thickness of the SiO₂ film (3.5 μm) was thin (Nos. 3 to 12), thermal resistance at 300°C or more was obtained, the scratch resistance was low.

[0096]

Experiment 2

The relationship between the SiO₂ film and scratch resistance was examined in Experiment 2.

[0097]

The ground aluminum substrate used in Experiment 1 was heated to 250°C, and then the SiO₂ film was deposited by the plasma CVD method, in the same way as in the Example 1 except that the film thickness of the SiO₂ film was set to 3.5 μm (test material 1), 6.1 μm (test material 2), 9 μm (test material 3), and 10.5 μm (test material 4).

[0098]

For reference, prepared as Reference Example 1 was an aluminum substrate on which a film was not deposited and which was used in the Experiment 1, and as Reference Example 2, the Ni-P plated substrate.

[0099]

Ni-P plating was degreased (Uemura Kogyo-made AD-68F), acid washed (Uemura Kogyo-made AD-107F), zincate treated (Uemura Kogyo-made AD-301 F3-X) and thereafter Ni-P plated using a mixture of Uemura Kogyo-made Nimuden HDX-7G and Uemura Kogyo-made HDX-A. The plating thickness was 10 μm.

[0100]

(Scratch resistance test)

The tip of the stylus (diamond sphere having a radius of 0.1 mm) to which a load of 10 g or 50 g was applied was caused to make contact with, and to slide on, the surface of a test material (film deposition surface). Sliding speed was set to a constant rate (5 mm/s) and a sliding distance to 15 mm. After sliding, the depth of the sliding mark on the surface of test material was measured with a noncontact optical roughness meter. Fig. 2 shows the results.

[0101]

Fig. 2 revealed the following. First, the depth of sliding mark of test material 1 in which the film thickness of the SiO₂ film was set to 3.5 μm was better than Reference Example 1 (aluminum alloy substrate); however, it was inferior to Reference Example 2 (Ni-P plated substrate) and did not have sufficient scratch resistance.

[0102]

On the other hand, when the film thickness of the SiO₂ film was set to be 6.1 μm (test material 2), 9 μm (test material 3) and 10.5 μm (test material 4), it was found that the film had superior scratch resistance as compared with Reference Example 1 (aluminum alloy substrate). Further, in the case of a load of 10 g, the depths of sliding marks of the 2 to 4 test materials were the same as in Reference Example 2, and this case had superior scratch resistance. Further in the case of a load of 50 g, the depth of sliding mark of the test material 2 (film thickness: 6 μm) was worsened than the Reference Example 2; however, the depth of sliding mark of each of the test material 3 (film thickness 9 μm) and the test material 4 (film thickness 10.5 μm) was better than Reference Example 2, and it was found

that they had more superior scratch resistance.

[0103]

Experiment 3

In Experiment 3, it was examined how the presence or absence of polishing of the SiO₂ film influences the surface roughness (center line average roughness Ra) of the SiO₂ film deposited on the surface of the aluminum alloy substrate.

[0104]

The test materials were prepared by depositing a SiO₂ film on the ground aluminum substrate used in the Experiment 1 in the same manner as Experiment 1 except that the film thickness of the SiO₂ film was set at 7 μm and the substrate temperature at 250°C.

[0105]

At that time, before depositing the SiO₂ film, the surface roughness of the aluminum substrate to be used was measured. The center line average roughness Ra was first measured as surface roughness of the aluminum substrate under an atomic force microscope (AFM). "Nanosurf easyScan2 FlexAFM" (2μm viewing angle) made by the Nanoscience Instruments-made was used as AFM.

[0106]

It should be noted that the measurement conditions for the center line average roughness Ra was configured based on the center line average roughness Ra, measured in two dimensions JIS B0601 (2001). As a result of measuring the centerline average roughness Ra, the center line average roughness Ra of the aluminum substrate before deposition of the SiO₂ film

was 8.9 nm.

[0107]

Next measured was the centerline average roughness R_a of the SiO_2 film that was deposited on an aluminum substrate. As a result, the center line average roughness R_a of the SiO_2 film was 8.9 nm ("the amount of polishing 0 μm " in Fig. 3), and was the same surface roughness before and after deposition of the SiO_2 film.

[0108]

Subsequently, the surface of the SiO_2 film was polished with a polishing machine (Speed Fam-made double-sided polishing machine 9B). A commercially available glass substrate polishing pad (Rodel Nitta-made RN-H pads) and polishing slurry (Fujimi-made Compol 20 polishing slurry) were used for the polishing action. It should be noted that conditions for the polishing action were set at a polishing pressure of 100 gf/cm^2 and a sliding speed of 60 cm/s , and the polishing amount was estimated assuming a density of the silica film ($2.2 \text{ g}/\text{cm}^3$) from the weight change before and after the polishing action.

[0109]

The center line average roughness R_a as measured after the SiO_2 film was polished by 0.39 μm was 0.45 nm, and the surface smoothness of the deposition of SiO_2 film was able to be greatly improved by the polishing action.

[0110]

The center line average roughness R_a as measured after the SiO_2 film was further polished by 0.60 μm was 0.27 nm, and it was verified that a

sufficiently smooth surface was able to be obtained by applying the method of polishing a glass substrate.

[0111]

This application is based on Japanese Patent Application No. 2012-285760, filed on December 27, 2012, the entire contents of which are incorporated herein.

[0112]

In order to embody the present invention, the present invention has been described fully and properly through exemplary embodiments with reference to the accompanying drawings in the foregoing description; however, it should be appreciated that modifications and/or improvement of the foregoing embodiments can readily be made by those skilled in the art. Therefore, unless modified or improved embodiment to be carried out by those skilled in the art corresponds to the one that departs from the scope of claims as set forth in the claims, the modified or improved embodiment should be interpreted as being comprehensive in the scope of the claims.

INDUSTRIAL APPLICABILITY

[0113]

The present invention has applicability to a wide range of industry, in the technical field in relation to an aluminum substrate, in particular, the aluminum substrate for magnetic recording medium, and a method of manufacturing it.

CLAIMS

[Claim 1]

An aluminum substrate for magnetic recording medium, the aluminum substrate having a SiO₂ film with a thickness of 6.0 μm or more and 15.0 μm or less deposited thereon,

wherein with the aluminum substrate heated at 150°C to 370°C, the SiO₂ film is deposited by a vapor phase deposition method.

[Claim 2]

The aluminum substrate according to claim 1, wherein the vapor phase deposition method is a plasma CVD method.