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DESCRIPTION

MAGNETIC RECORDING MEDIUM AND PRODUCTION PROCESS THEREOF

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a magnetic recording medium used in a magnetic disk drive or other magnetic recording device, and a production process thereof.

Description of Related Art

Hard disk drives, which are magnetic recording devices used as storage devices of information processing devices, are provided with a magnetic head for playback and recording, and a magnetic recording medium in the form of a magnetic disk having a magnetic layer. The magnetic layer in a magnetic disk is formed by depositing a ferromagnetic metal or alloy thereof on a non-magnetic substrate by sputtering, vapor deposition or electroless plating and so forth. In general, a so-called contact start stop (CSS) method is employed in hard disk drives for recording and playback of data. In hard disk drives employing the CSS method, the magnetic head is in contact with the magnetic disk (to also be simply referred to as a disk) at the start of operation, and when the disk begins to rotate, the magnetic head slides over the disk, and as the rotating speed

of the disk increases, the magnetic head lifts from the disk and recording and playback are carried out in this state. When stopping, the magnetic head again slides over the disk when the rotating speed of the magnetic disk decreases.

In magnetic disks, in order to prevent deterioration of the durability of the magnetic disk due to abrasive damage caused by sliding contact with the magnetic head, a protective film layer and lubricant layer are provided on the magnetic layer to improve the wear resistance of the magnetic disk as well as reduce static friction and dynamic friction when the magnetic head and magnetic make sliding contact. Films such as carbon films, SiO_2 , ZrO_2 and other oxide films, nitride films and boride films have typically been used for the aforementioned protective film layer.

In addition, the aforementioned lubricant layer is typically formed by coating a lubricant such as a liquid perfluoropolyether compound onto the surface of the disk.

In magnetic disks, the amounts and properties of freely moving molecules in the lubricant layer along with molecules in the lubricant layer that bond to the surface of the protective film layer have an important effect on wear resistance. For example, if the amount of freely moving molecules in the lubricant layer is too great, the static friction coefficient of the disk increases, resulting in increased susceptibility

to the occurrence of adsorption phenomena (so-called stiction) between the magnetic head and disk. If the amount is too low, the dynamic friction coefficient of the magnetic disk surface increases, resulting in decreased lubricity and increased susceptibility to the occurrence of the head crash.

In order to reduce stiction, the contact surface area between the head and disk is reduced by giving a certain level of roughness referred to as texturing to the disk surface, or by imparting low bumps formed by irradiating with laser light referred to as laser texturing. However, the flying height of the magnetic head over the disk has recently become extremely low at 25 nm or less in order to achieve higher recording densities. Thus, it is necessary to make the disk surface as smooth as possible and reduce the height of the bumps formed by laser texturing to avoid contact between the disk and head while driving is starting. However, when this is done, stiction conversely worsens. Since stiction cannot be adequately reduced by bumps formed by laser texturing alone, it is necessary to also control the amounts and properties of freely moving molecules in the lubricant layer as well as the molecules in the lubricant layer that bond to the surface of the protective film layer as previously described.

The lubricant layer is required to enhance the bonding strength with the protective film layer accompanying increased

recording density. This is required for the reasons indicated below. Hard disk drives are becoming increasingly compact and lightweight through the use of magnetic heads, MR elements, GMR elements and so forth for the purpose of improving recording density, and startup operation is required to be improved by lowering the static friction coefficient in order to reduce the initial drive force that also constitutes the load on the magnetic head. In order to reduce the static friction coefficient, it is effective to reduce the amount of freely moving molecules in the lubricant layer by increasing the bonding strength between the lubricant and protective film layer.

The ramp load method has also come to be used practically in recent years in addition to the CSS (Contact Start Stop) method. The ramp load method refers to a method that employs a mechanism by which a head evacuation area is provided near the outer periphery of the disk, and the head is then housed in that evacuation area when rotation of the disk is stopped. In this method, since the head does not make contact with the disk when the disk is stationary, there is said to be no concern over stiction as with the CSS method. However, it has been determined that it is necessary to reduce adsorption of the head to the disk in the ramp load method as well in order to reduce behavioral changes in the head when the head and disk

inadvertently make contact. Thus, it is important to reduce the static friction coefficient in the ramp load method as well.

In addition, disk rotating speed has been increased during recording and playback in order to improve recording density. In the case of increasing rotating speed, a so-called spin-off phenomenon occurs in which lubricant is scattered due to centrifugal force. As a result, the problem occurs in which the film thickness of the lubricant layer decreases. It is again desirable to increase the bonding strength with the protective film layer in order to prevent spin-off and enhance durability. Furthermore, the bonded ratio is used as an indicator of the bonding strength between the lubricant and protective film layer. This value indicates the proportion (%) of lubricant that remains when a magnetic disk on which a lubricant layer has been formed is washed with a fluorine-based solvent (for example, AS225 manufactured by Asahi Glass Co., Ltd.), and provides a general reference of the bonding strength of the lubricant to the protective film layer.

Consequently, various types of treatments have attempted to be carried out on the lubricant layer for the purpose of enhancing the bonding strength of the lubricant layer to the protective film layer. For example, a method is disclosed in Japanese Unexamined Patent Application, Publication No. H11-25452 in which heat treatment is carried out on a coated

lubricant followed by ultraviolet radiation treatment. In addition, a method is disclosed in Japanese Unexamined Patent Application, Publication No. H8-124142 in which a lubricant layer is formed followed by irradiating the lubricant layer with ultraviolet light at a wavelength of 150 to 180 nm. In addition, a method is disclosed in Japanese Unexamined Patent Application, Publication No. H7-85461 in which a lubricant layer is coated onto a hydrogenated carbon protective film followed by irradiation with ultraviolet light. In addition, a method is disclosed in Japanese Unexamined Patent Application, Publication No. H5-217162 in which a lubricant is coated onto a carbon protective film followed by subjecting to heat treatment. In addition, a method is disclosed in Japanese Unexamined Patent Application, Publication No. S62-150526 in which plasma treatment is carried out on a protective film.

However, in the production processes of magnetic recording media of the prior art in which a lubricant layer and protective film are formed by these treatment methods, it was difficult to produce a magnetic recording medium in which the bonding strength of the lubricant layer to the protective film layer was enhanced without increasing the dynamic friction coefficient. Consequently, there is a need for a magnetic recording medium having superior startup operation and durability while also obtaining adequate surface lubricity.

In addition, magnetic recording medium are required to indicate durability with respect to corrosion in addition to the aforementioned objects.

Substrates consisting of performing NiP plating on an Al substrate and glass substrates containing Li and Na are primarily used for the non-magnetic substrates used in magnetic recording media. In addition, Co-based alloys are used for the magnetic layer. Ni, Li, Na and Co do not precipitate onto the surface of the magnetic recording medium if there is a fine protective film. However, if the protective film is not fine or small pits form, elements such as Ni, Li, Na and Co form oxides and hydroxides from those locations, and these end up precipitating onto the surface of the magnetic recording medium. This is referred to as corrosion.

Although corrosion occurs in various forms, it frequently exceeds 25 nm in height. The height of corrosion is typically 100 to 10000 nm. Thus, if corrosion occurs, the head ends up colliding with the corrosion resulting in head crash.

In consideration of the aforementioned circumstances, the object of the present invention is to obtain a magnetic recording medium having superior startup operation and durability, satisfactory surface lubricity and superior corrosion characteristics.

SUMMARY OF THE INVENTION

As a result of extensive studies to solve the aforementioned problems, the inventors of the present invention found that, in a production process in which a protective film layer is surface treated using a treatment gas activated by glow discharge plasma generated under pressure in the vicinity of atmospheric pressure, by using a sine wave high-frequency power supply for the power supply that generates the plasma, not only is it possible to enhance the bonding strength of the lubricant to the protective film layer, lower the static friction coefficient, improve startup operation, enhance durability and obtain superior surface lubricity, but corrosion properties can also be improved, thereby leading to completion of the present invention.

Namely, the present invention employs the following constitution to achieve the aforementioned object.

(1) A production process of a magnetic recording medium comprising sequentially laminating at least a magnetic layer, a protective film layer and a lubricant layer on a non-magnetic substrate, and surface treating the protective film layer using a gas activated by plasma generated under pressure in the vicinity of atmospheric pressure; wherein, a sine wave high-frequency power supply is used for the power supply that generates the plasma.

(2) The production process of a magnetic recording medium as described in the aforementioned (1), wherein the frequency of the power supply is within the range of 1 kHz to 100 kHz.

(3) The production process of a magnetic recording medium as described in the aforementioned (1) or (2), wherein the plasma is glow discharge plasma.

(4) The production process of a magnetic recording medium as described in any of the aforementioned (1) to (3), wherein the surface of the protective film layer is treated using the activated gas after forming the protective film layer, followed by formation of the lubricant layer.

(5) The production process of a magnetic recording medium as described in any of the aforementioned (1) to (4), wherein the gas contains at least one type of gas selected from the group consisting of nitrogen, oxygen and argon.

(6) The production process of a magnetic recording medium as described in any of the aforementioned (1) to (5), wherein the plasma generated at a pressure in the vicinity of atmospheric pressure is a plasma generated by applying an electric field between opposing electrodes.

(7) The production process of a magnetic recording medium as described in the aforementioned (6), wherein the opposing electrodes are arranged at an angle of 1 degree to 45 degrees from perpendicular to a treated substrate in which at least the

magnetic layer and protective film layer are formed on the non-magnetic substrate.

(8) The production process of a magnetic recording medium as described in the aforementioned (6), wherein the opposing electrodes are formed perpendicular to a treated substrate in which at least the magnetic layer and the protective film layer are formed on the non-magnetic substrate.

(9) The production process of a magnetic recording medium as described in the aforementioned (6), wherein surface treatment is carried out on the protective film layer by arranging a treated substrate, in which at least the magnetic layer and the protective film layer are formed on the non-magnetic substrate, between the opposing electrodes.

(10) The production process of a magnetic recording medium as described in any of the aforementioned (1) to (9), wherein surface treatment using the activated gas is simultaneously carried out on both sides of a treated substrate in which at least the magnetic layer and the protective film layer are formed on the non-magnetic substrate.

(11) The production process of a magnetic recording medium as described in any of the aforementioned (1) to (10), wherein the non-magnetic substrate is one type of substrate selected from a glass substrate and a silicon substrate.

(12) The production process of a magnetic recording medium

as described in any of the aforementioned (1) to (10), wherein the non-magnetic substrate has a film comprised of NiP or NiP alloy formed on the surface of a base comprised of one type of material selected from Al, Al alloy, glass and silicon.

(13) A magnetic recording medium produced according to the production process of a magnetic recording medium as described in any of the aforementioned (1) to (12).

(14) A magnetic recording and playback device provided with a magnetic recording medium and a magnetic head that records and plays back data onto said magnetic recording medium; wherein, the magnetic recording medium is the magnetic recording medium as described in the aforementioned (13).

(15) A surface treatment device that has the function of forming an activated gas by generating plasma by applying an electric field between opposing electrodes under pressure in the vicinity of atmospheric pressure, and radiating the activated gas onto the surface of a treated substrate in which at least a magnetic layer and a protective film layer are formed on a non-magnetic substrate.

The invention of the present application is similar to Japanese Unexamined Patent Application, Publication No. S62-150526 in that it uses plasma to improve the surface characteristics of the protective film. However, in contrast to the technology described in Japanese Unexamined Patent

Application, First Publication No. S62-150526 carrying out plasma treatment in a vacuum, the invention of the present application is quite different in that plasma treatment is carried out at a pressure in the vicinity of atmospheric pressure. If plasma treatment is carried out in a vacuum, since the activated treatment gas contacts the surface of the protective film without losing hardly any of its activity, a portion of the protective film itself ends up being etched. On the other hand, if treatment gas is used that has been treated with plasma at a pressure in the vicinity of atmospheric pressure, its activity decreases due to the frequent occurrence of collisions between its molecules due to its extremely high molecular density, thereby making it suitable for surface treatment of the protective film. In addition, the vacuum device used for plasma treatment in a vacuum is large due to comprising components such as a vacuum chamber, exhaust pump and transport system for transporting from atmospheric pressure to a vacuum, and also ends up being expensive. On the other hand, in the case of treating with plasma at a pressure in the vicinity of atmospheric pressure, vacuum equipment is not required, making it possible to achieve simplification of the device and reduced costs.

In addition, in the production of a magnetic recording medium, a step is typically contained in which, following

deposition of the protective film, it is washed with a liquid such as water, acid or base to remove dust that has become adhered inside the vacuum device. If plasma treatment is carried out in a vacuum, surface modification characteristics end up deteriorating severely since the protective film surface ends up getting wet in the subsequent washing step. Although plasma treatment must be carried out after the washing step to prevent this, since this requires an additional vacuum device, there is a considerable increase in costs. On the other hand, in the case of carrying out plasma treatment at the vicinity of atmospheric pressure, alteration of the device is not necessary even if carried out after a washing step, thereby not leading to any increases in costs.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a cross-sectional view showing one embodiment of a magnetic recording medium of the present invention.

Fig. 2 is a schematic block drawing showing one embodiment of a plasma generation unit used to produce a magnetic recording medium of the present invention.

Fig. 3 is a schematic block drawing showing another embodiment of a plasma generation unit used to produce a magnetic recording medium of the present invention.

Fig. 4 is a schematic block drawing showing another

embodiment of a plasma generation unit used to produce a magnetic recording medium of the present invention.

Fig. 5 is a schematic block drawing showing another embodiment of a plasma generation unit used to produce a magnetic recording medium of the present invention.

Fig. 6 is a schematic block drawing showing another embodiment of a plasma generation unit used to produce a magnetic recording medium of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The following provides an explanation of embodiments of the present invention with reference to the drawings.

Fig. 1 is a cross-sectional view showing one embodiment of a magnetic recording medium of the present invention.

A magnetic recording medium of the present embodiment is composed by sequentially laminating a substrate layer 2, an intermediate layer 3, a magnetic layer 4 and a protective film layer 5 on a non-magnetic substrate 1, and providing a lubricant layer 6 on the uppermost layer.

Examples of materials that can be used for non-magnetic substrate 1 include metal materials such as aluminum and aluminum alloy, inorganic materials such as glass, ceramics, titanium, carbon and silicon, and polymer compounds such as polyethylene terephthalate, polyimide, polyamide,

polycarbonate, polysulfone, polyethylene naphthalate, polyvinyl chloride and cyclic hydrocarbon-containing polyolefin. In addition, one or more types of films selected from NiP, NiP alloy and other alloys can be vapor deposited by plating or sputtering and so forth onto the surfaces of these substrates.

The material of substrate layer 2 can be composed with Cr or Cr alloy composed of Cr and one or more types of metals selected from Ti, Mo, Al, Ta, W, Ni, B, Si, Mn and V.

In the case of substrate layer 2 being a non-magnetic substrate layer having a multilayered structure, at least one of the constituent layers that compose the non-magnetic substrate layer can be composed with the aforementioned Cr alloy or Cr.

The aforementioned non-magnetic substrate layer can also be composed with an NiAl-based alloy, RuAl-based alloy or Cr alloy (alloy composed of Cr and one or more types selected from Ti, Mo, Al, Ta, W, Ni, B, Si and V).

In the case the non-magnetic substrate layer has a multilayered structure, at least one of the constituent layers that compose the non-magnetic substrate layer can be composed with an NiAl-based alloy, RuAl-based alloy or the aforementioned Cr alloy.

The material of intermediate layer 3 is used for the purpose

of assisting the epitaxial growth of Co alloy, and is preferably a non-magnetic material having an hcp structure that is a Co alloy having Co as its main raw material. Preferable examples include materials containing any one type selected from Co-Cr-based alloy, Co-Cr-Ru-based alloy, Co-Cr-Ta-based alloy and Co-Cr-Zr-based alloy.

The material of magnetic layer 4 is preferably material having an hcp structure that is a Co alloy having Co as its main raw material. Preferable examples include materials containing any one type selected from Co-Cr-Ta-based alloy, Co-Cr-Pt-based alloy, Co-Cr-Pt-Ta-based alloy, Co-Cr-Pt-B-based alloy and Co-Cr-Pt-B-Cu-based alloy.

A carbon-based material such as amorphous carbon, hydrogen-containing carbon and fluorine-containing carbon, or a ceramic-based material such as silica and zirconia can be used for protective film layer 5. In particular, hard, dense CVD carbon is used preferably in terms of not only its durability, but also its economy and productivity. Since the durability of protective film layer 5 decreases if its thickness is excessively thin, while loss during recording and playback increases if its thickness is excessively thick, the film thickness of protective film layer 5 is set to 10 to 150 Å (1 to 15 nm), and preferably set to 20 to 60 Å (2 to 6 nm). Protective film layer 5 is subjected to surface treatment using

a gas (treatment gas) activated by plasma to be described later.

The uppermost lubricant layer 6 contains a polymer of a polymerizeable unsaturated group-containing perfluoropolyether compound. Examples of polymerizeable unsaturated group-containing perfluoropolyether compounds include compounds comprised by bonding an organic group having a polymerizeable unsaturated bond to at least one end of perfluoropolyether serving as the main chain.

A magnetic recording and playback device of the present embodiment is provided with the aforementioned magnetic recording medium having protective film layer 5 on which surface treatment has been carried out with the aforementioned treatment gas, and a magnetic head that records and plays back information on said magnetic recording medium.

The following provides an explanation of an example of a production process of a magnetic recording medium of the present embodiment.

First, after forming substrate layer 2, intermediate layer 3, magnetic layer 4 and a protective film layer on non-magnetic substrate 1, surface treatment is performed on this protective film layer using a gas that has been activated by plasma generated under pressure in the vicinity of atmospheric pressure to form protective film layer 5. Next, lubricant layer 6 is formed on this protective film layer 5. The aforementioned

plasma is preferably glow discharge plasma.

A plasma generation unit capable of stable generation of plasma at a pressure in the vicinity of atmospheric pressure, and which uses a sine wave high-frequency power supply for the power supply that generates the plasma, can be used for the surface treatment device used here for surface treatment.

Examples of devices that can be used include a normal pressure plasma surface modification device (Esquare) and an atmospheric pressure plasma cleaning head (Matsushita Electric Works).

A pressure in the vicinity of atmospheric pressure refers to pressure of 1.3×10^4 to 13×10^4 Pa. In particular, the use of a pressure in the vicinity of atmospheric pressure of 9.9×10^4 to 10.3×10^4 Pa is preferable since it facilitates pressure regulation and simplifies the device constitution.

The following provides an explanation of a plasma generation unit of the present embodiment using Fig. 2.

The plasma generation unit of Fig. 2 is primarily composed by a pair of opposing electrode plates (opposing electrodes) 21a and 21b, a gas inlet port 22 for supplying gas between electrode plates 21a and 21b, a plasma generation power supply 23 that applies an electric field between the opposing electrodes, and a substrate holder 26 for holding a treated substrate 25.

Treated substrate 25 has at least a magnetic layer and a protective film layer prior to surface treatment formed on a non-magnetic substrate, and in the case of the present embodiment, has a substrate layer 2, intermediate layer 3, magnetic layer 4 and a protective film layer prior to surface treatment formed on a non-magnetic substrate 1.

This plasma generation unit has the function of forming a gas that has been activated by generating plasma by applying an electric field between the pair of opposing electrode plates 21a and 21b at a pressure in the vicinity of atmospheric pressure, and radiating the activated gas onto the surface of treated substrate 25.

Iron, copper, aluminum or alloys thereof is used for the material of each electrode plate. Although the distance between the opposing electrodes is preferably 0.1 to 50 mm, it is more preferably 0.1 to 5 mm in consideration of the stability of plasma discharge.

Each electrode plate is preferably covered with a dielectric substance. Covering each electrode plate with a dielectric substance makes it possible to prevent oxidation and nitridation of the metal that composes the electrodes by the plasma. An oxide such as aluminum oxide (Al_2O_3) is preferably used for the material of the dielectric substance.

A high-frequency sine wave is used for the electric field

applied between electrode plates 21a and 21b. The use of a sine wave frequency of 1 to 100 kHz, and particularly 10 to 50 kHz, is preferable in consideration of stability of the plasma discharge.

In the present invention, the use of sine waves is advantageous for the reasons indicated below.

In the case of comparing sine waves with pulse waves, it is necessary to increase the peak voltage in the case of pulse waves since pulse waves normally used for plasma discharge have a lower duty ratio. For example, normal conditions for use for plasma discharge consist of a frequency of 10 kHz, pulse width of 10 μ sec (duty ratio: 10%) and peak voltage of 30000 V. On the other hand, in the case of sine waves, the peak voltage can be lowered since although the waves are in the form of sine waves, voltage can be applied continuously. For example, the peak voltage is 10000 V for a frequency of 10 kHz.

Although the relationship between peak voltage and corrosion is not completely understood, it can be easily imagined that a higher peak voltage would most likely result in increased likelihood of the occurrence of micro-arcing. Although there are various reasons for the occurrence of corrosion, it is widely known that, if small pits form in a protective film, the Ni, Li, Na, Co and so forth contained in the substrate and magnetic layer ends up dispersing from those

pits onto the surface of the protective film. If micro-arcining occurs, small pits end up forming in the protective film, which in turn is believed to result in the generation of corrosion.

In the case of using high-frequency sine waves, it is preferable to match impedance between the electrodes on the load side and the power supply on the supply side. If impedance is not matched, reflection waves end up being generated resulting in unstable operation and increased likelihood of micro-arcining.

Impedance on the electrode side may fluctuate depending on the type of reaction gas (nitrogen, oxygen, argon or mixtures thereof) or the material and size of the treated substrate. In this case, impedance can be matched by allowing the oscillation frequency of the power supply side to change in response to a change in impedance on the electrode side using a PLL circuit. Furthermore, a PLL circuit refers to a phase-locked loop for generating a new signal synchronized with the phase of a signal of a certain frequency, and is one technique used for stable operation of high-frequency circuits.

Nitrogen, oxygen, argon or a mixture thereof is preferably used for the gas supplied between electrode plates 21a and 21b. Since the amount of gas consumed is large due to using at a pressure in the vicinity of atmospheric pressure, inexpensive nitrogen, oxygen or a mixed gas of nitrogen and oxygen is used more preferably.

In Fig. 2, a pair of electrode plates 21a and 21b are arranged perpendicular to a protective film layer prior to surface treatment (treated substrate 25). Although plasma is generated between the electrodes, since the generated plasma spreads out, a plasma state is also generated at portions where the plasma spills out from between the electrodes. The distance from one end of the opposing electrode plates to the protective film layer (treated substrate 25) is preferably 0.1 to 5 mm. If this distance is less than 0.1 mm, there is the risk of treated substrate 25 being crushed by the electrode plates, thus making this undesirable. If this distance exceeds 5 mm, since the plasma spreads excessively causing effects to decrease considerably, surface treatment effects are not obtained. Gas supplied between the pair of electrode plates 21a and 21b under pressure in the vicinity of atmospheric pressure becomes treatment gas as a result of being activated by plasma generated between these electrodes, and since this treatment gas has an extremely high molecular density, activity decreases due to the frequent occurrence of collisions between molecules, thereby making it suitable for surface treatment of a protective film.

It is preferable to use a transport method that does not contact both surfaces of the substrate in order to use both sides of a magnetic recording medium (magnetic disk). Thus, it is preferable to transport treated substrate 25 by holding onto

the inside edge or outside edge. The transport speed is preferably 10 to 6000 mm/minute. A transport speed of 100 to 3000 mm/minute is more preferable in consideration of high throughput and surface treatment effects. The transport method may consist of moving treated substrate 25 or moving the plasma generation unit. An example of a transport method that moves treated substrate 25 consists of moving treated substrate 25 by using a substrate holder 26 that has a function that enables it to be raised and lowered to sequentially treat the surface of the protective film layer with treatment gas.

As shown in Fig. 3, in order to use both sides of a magnetic recording medium, it is preferable to arrange plasma generation units on both sides of treated substrate 25 as previously described, and carry out surface treatment using a gas activated by plasma generated at a pressure in the vicinity of atmospheric pressure on both sides of treated substrate 25.

In the case of transporting by holding onto an inside edge or outside edge of treated substrate 25, the inside edge or outside edge of treated substrate 25 ends up being concealed by the shadow of holder 26, resulting in the risk of a decrease in surface treatment effects at the concealed locations. In order to prevent this, it is preferable that the opposing pair of electrode plates 21a and 21b be arranged inclined at an angle of 1 to 45 degrees from perpendicular with respect to the

protective film layer prior to surface treatment (treated substrate 25) as shown in Fig. 4. Furthermore, Fig. 4 shows an example of a device in the case of transporting treated substrate 25 by holding onto its outside edge.

If surface treatment is carried out by arranging the pair of opposing electrode plates 21a and 21b inclined at an angle of 1 to 45 degrees from perpendicular with respect to treated substrate 25, since the plasma is irradiated on an incline with respect to the protective film, treatment gas activated by plasma also contacts the portion concealed by the shadow of holder 26. In this case as well, it is preferable to arrange plasma generation units on both sides of treated substrate 25 as shown in Fig. 5.

A protective film layer of treated substrate 25 can also be surface treated by passing treated substrate 25 between the pair of opposing electrode plates 21a and 21b as shown in Fig. 6. In this case, more powerful surface treatment can be carried out since the plasma density is higher.

[Examples 1 to 17]

After adequately washing and drying an aluminum alloy substrate having an NiP plated film (diameter: 95 mm, inner diameter: 25 mm, thickness: 1.27 mm), it was irradiated with a laser from a radius of 17 mm to 19 mm (CSS zone) to form bumps having a height of 10 nm. Subsequently, the substrate was

placed in a DC Magnetron Sputtering System (Model C3010, Anelva). After evacuating the air to an attainable vacuum of 2×10^{-7} Torr (2.7×10^{-5} Pa), the substrate was heated to 250°C.

Following heating, a non-magnetic substrate layer was laminated to a thickness of 5 nm using a target composed of Cr. Moreover, a non-magnetic substrate layer was laminated to a thickness of 5 nm using a target composed of Cr-Mo alloy (Cr: 80 at%, Mo: 20 at%). Next, a non-magnetic intermediate layer was laminated to a thickness of 2 nm using a target composed of Co-Cr alloy (Co: 65 at%, Cr: 35 at%). Next, a magnetic layer in the form of a CoCrPtB alloy layer was formed as a magnetic layer at a film thickness of 20 nm using a target composed of Co-Cr-Pt-B alloy (Co: 60 at%, Cr: 22 at%, Pt: 12 at%, B: 6 at%), and a protective film composed of CVD carbon was laminated to a thickness of 5 nm using a plasma CVD system to obtain a treated substrate. The argon pressure during film deposition was set to 6 mTorr (0.8 Pa). Following deposition through deposition of the protective film, the substrate was removed from the vacuum system, washed with pure water using a spin coater and dried. Subsequently, the protective film surface of the treated substrate was surface treated in the manner shown in Fig. 2 using a normal pressure plasma surface modification unit (Esquare) for the plasma generation unit. A sine wave high-frequency power supply was used for the plasma generation

power supply. The power supply output was set to 1 kw. Since this surface treatment device is equipped with a PLL circuit, the frequency is fluctuated to prevent resonance. Thus, the sine wave frequency is controlled to between 12 to 17 kHz. The transport speed, N₂ flow rate, O₂ flow rate, and distance from one end of the opposing electrodes (end nearest the treated substrate) to the protective film on the treated substrate were changed as shown in Table 1.

The contact angle of these samples were measured with a water contact gauge. Those results are shown in Table 1.

Following the aforementioned surface treatment, a lubricant composed of perfluoropolyether was coated onto the protective film layer at a pulling rate of 3 mm/sec by a dipping method after adjusting to 0.05% by weight to obtain a magnetic disk (sample). Furthermore, fluorine-based solvent AK225 (Asahi Glass) was used for the solvent at this time.

[Comparative Example 1]

Furthermore, a sample was produced in the same manner as the aforementioned method with the exception of not carrying out the aforementioned surface treatment on the protective film layer for the sake of comparison.

The lubricant film thicknesses of each of the samples produced were measured using FTIR. Those results are shown in Table 1. In addition, bonded ratio was measured in the manner

described below to serve as an indicator of bonding strength of the lubricant layer to the protective film layer. After washing the surface of the aforementioned magnetic disk by immersing in fluorine-based solvent AK225 (Asahi Glass) for 15 minutes, the thicknesses of the lubricant layer before and after washing were measured using FTIR at a location at a radius of 20 mm, and the thickness of the lubricant layer after washing versus the lubricant layer thickness before washing was taken to be the bonded ratio (%). Those results are shown in Table 1.

Dynamic friction coefficients were also measured. A CSS (Contact Start Stop) durability test was carried out under conditions of a temperature of 25° and humidity of 60% RH. In this test, 10,000 CSS operations (consisting of rotating at a rotating speed of 10,000 rpm (maintained for 1 second) and stopping (1 second), and repeating at 5 second intervals) were carried out in the CSS zone using a CSS tester and a reference MR head (DLC coating, 30% slider, load: 2.5 g) for the magnetic head. The dynamic friction coefficients of the magnetic disk surface after 10,000 CSS operations are shown in Table 1.

Static friction coefficients were also measured. A CSS (Contact Start Stop) durability test was carried out under conditions of a temperature of 25° and humidity of 60% RH. In this test, 10,000 CSS operations (consisting of rotating at a

rotating speed of 10,000 rpm (maintained for 1 second) and stopping (1 second), and repeating at 5 second intervals) were carried out in the CSS zone using a CSS tester and a reference MR head (DLC coating, 30% slider, load: 2.5 g) for the magnetic head. The static friction coefficients of the magnetic disk surface after 10,000 CSS operations are shown in Table 1.

Film thickness reduction rates were also measured (spin-off test). The magnetic disk was rotated for 72 hours in an environment at 80°C and at a rotating speed of 10,000 rpm. The thickness of the lubricant layer at a location at a radius of 20 mm was measured before and after this operation, and the reduction rates of film thickness of the lubricant layer before and after testing were measured with FTIR. Those results are shown in Table 1.

Furthermore, although the units of the values shown for lubricant film thickness are in angstroms, they can be converted to nanometers by multiplying 0.1 by the values shown for lubricant film thickness in the table.

A corrosion test was also carried out. Samples were allowed to stand for 96 hours at a temperature of 80°C and humidity of 85% RH. The surfaces of the samples were observed with a microscope and the number of corrosion spots were counted. Foreign objects measuring 1 μm or larger were observed and counted as corrosion spots over the entire surface.

Furthermore, the surfaces of the samples were confirmed to be free of foreign objects measuring 1 μm or larger before conducting the corrosion test.

[Comparative Examples 2 to 4]

The protective film layers of treated substrates were surface treated in the same manner as Example 1 using a normal pressure plasma surface modification unit (Sekisui Chemical). A pulse power supply was used for the power supply that generated the plasma. The frequency was set to 30 kHz and the pulse width was set to 10 μsec . Other treatment conditions were the same as in Example 1. The transport speed, N_2 flow rate, O_2 flow rate, and distance from one end of the opposing electrodes (end nearest the treated substrate) to the protective film on the treated substrate were changed as shown in Table 1.

Table 1

	Trans- port speed	N ₂ flow rate	O ₂ flow rate	Distance from opposing electrode end to protective film	Contact angle	Lubri- cant film thick- ness	Bonded Ratio	Dyna- mic friction coeff.	Static fric- tion coeff.	Film thick- ness reduc- tion ratio	Cor- rosion spots
	mm/min	l/min	ml/min	mm	Deg.	Å	%			%	No.
Ex. 1	500	40	10	2	5.6	20.6	71	0.34	0.42	2	6
Ex. 2	1000	40	10	2	10.3	20.5	73	0.37	0.43	3	4
Ex. 3	2000	40	10	2	11.6	20.7	74	0.33	0.41	4	2
Ex. 4	4000	40	10	2	12.7	20.1	72	0.31	0.47	6	0
Ex. 5	2000	40	10	1	9.4	20.9	71	0.34	0.41	2	1
Ex. 6	2000	40	10	3	11.2	20.1	74	0.36	0.43	3	2
Ex. 7	2000	40	10	5	14.5	19.6	70	0.32	0.50	5	5
Ex. 8	2000	40	10	10	17.3	18.3	61	0.34	0.55	12	0
Ex. 9	2000	1	10	2	20.4	18.4	57	0.35	0.71	11	0
Ex. 10	2000	10	10	2	17.2	18.5	64	0.37	0.66	9	0
Ex. 11	2000	20	10	2	14.3	19.4	67	0.31	0.61	8	0
Ex. 12	2000	100	10	2	7.8	20.6	75	0.34	0.41	5	4
Ex. 13	2000	200	10	2	6.4	20.7	78	0.33	0.45	4	2
Ex. 14	2000	40	0	2	25.4	18.2	54	0.36	0.41	4	0
Ex. 15	500	40	0	2	10.4	20.1	75	0.31	0.44	4	0
Ex. 16	2000	40	20	2	7.8	20.4	70	0.37	0.43	5	3
Ex. 17	2000	40	40	2	6.4	20.6	72	0.39	0.40	3	2
Comp. Ex. 1	No plasma treatment				44.7	17.3	41	0.31	1.30	17	0
Comp. Ex. 2	600	40	0	2	3.8	20.2	69	0.39	0.50	3	481
Comp. Ex. 3	1000	40	0	2	3.9	20.7	72	0.34	0.51	5	394
Comp. Ex. 4	600	40	0	5	10.1	18.6	57	0.35	0.78	8	97

As can be seen from the results shown in Table 1, the contact angles decreased significantly from 44.7 degrees (Comparative Example 1) to 5.6-25.4 degrees (Examples 1 to 17) as a result of carrying out plasma treatment. Accompanying these decreases in the contact angle, the bonded ratios improved considerably from 41% (Comparative Example 1) to 54-78% (Examples 1 to 17). This means that the number of freely moving molecules of the lubricant decreased, and as a result, the static friction coefficients improved considerably from 1.30 (Comparative Example 1) to 0.40-0.71 (Examples 1 to 17), and the film thickness reduction rates as determined from the spin-off test also improved considerably from 17% (Comparative Example 1) to 2-12%. Furthermore, in the examples, the contact angle was determined to increase as the distance from one end of the opposing electrodes to the protective film increased.

In the examples, the effects of surface treatment were not observed if the distance from one end of the opposing electrodes to the protective film layer is 10 mm.

In addition, although corrosion spots are not observed if plasma treatment is not carried out (Comparative Example 1), if a normal pressure plasma surface modification unit is used, corrosion spots are observed on the order of about 100 to 500 (Comparative Examples 2 to 4). On the other hand, if a normal pressure surface modification unit that uses sine waves is used,

the number of corrosion spots is observed to decrease significantly to 0 to 6 spots (Examples 1 to 17).

On the basis of the above results, as a result of carrying out plasma surface treatment using a normal pressure plasma surface modification unit using sine waves on a protective film layer at a pressure in the vicinity of atmospheric pressure, contact angle was found to improve considerably, and as a result, adhesion of lubricant was also observed to improve. As a result, not only can the static friction coefficient be adequately lowered, startup operation improved and durability enhanced by preventing spin-off phenomenon, satisfactory surface lubricating characteristics can also be obtained. Moreover, a magnetic recording medium having satisfactory corrosion characteristics can be obtained.

According to the production process of a magnetic recording medium of the present invention, a magnetic recording medium can be produced that has superior startup operation and durability, satisfactory surface lubricity and superior corrosion characteristics.

A magnetic recording medium of the present invention has superior startup operation and durability, satisfactory surface lubricity and superior corrosion characteristics.

CLAIMS

1. A production process of a magnetic recording medium comprising sequentially laminating at least a magnetic layer, a protective film layer and a lubricant layer on a non-magnetic substrate, and surface treating the protective film layer using a gas activated by plasma generated under pressure in a vicinity of atmospheric pressure; wherein,

a sine wave high-frequency power supply is used for the power supply that generates the plasma.

2. The production process of the magnetic recording medium according to claim 1, wherein the frequency of the power supply is within the range of 1 kHz to 100 kHz.

3. The production process of the magnetic recording medium according to claim 1, wherein the plasma is glow discharge plasma.

4. The production process of the magnetic recording medium according to claim 1, wherein the surface of the protective film layer is treated using the activated gas after forming the protective film layer, followed by formation of the lubricant layer.

5. The production process of the magnetic recording medium according to claim 1, wherein the gas contains at least one type of gas selected from a group consisting of nitrogen, oxygen and argon.

6. The production process of the magnetic recording medium according to claim 1, wherein the plasma generated at pressure in the vicinity of the atmospheric pressure is a plasma generated by applying an electric field between opposing electrodes.

7. The production process of the magnetic recording medium according to claim 6, wherein the opposing electrodes are arranged at an angle of 1 degree to 45 degrees from perpendicular to a substrate to be treated in which at least the magnetic layer and the protective film layer are formed on the non-magnetic substrate.

8. The production process of the magnetic recording medium according to claim 6, wherein the opposing electrodes are formed perpendicular to a substrate to be treated in which at least the magnetic layer and the protective film layer are formed on the non-magnetic substrate.

9. The production process of the magnetic recording medium according to claim 6, wherein surface treatment is carried out on the protective film layer by arranging a substrate to be treated, in which at least the magnetic layer and the protective film layer are formed on the non-magnetic substrate, between the opposing electrodes.

10. The production process of the magnetic recording medium according to claim 1, wherein surface treatment using the activated gas is simultaneously carried out on both sides of a substrate to be treated in which at least the magnetic layer and the protective film layer are formed on the non-magnetic substrate.

11. The production process of the magnetic recording medium according to claim 1, wherein the non-magnetic substrate is one type of substrate selected from a glass substrate and a silicon substrate.

12. The production process of the magnetic recording medium according to claim 1, wherein the non-magnetic substrate has a film comprised of NiP or NiP alloy formed on the surface of a base comprised of one type of material selected from Al, Al alloy, glass and silicon.

13. A magnetic recording medium produced by the production process of a magnetic recording medium according to claim 1.

14. A magnetic recording and playback device provided with a magnetic recording medium and a magnetic head that records and plays back data onto the magnetic recording medium; wherein, the magnetic recording medium is the magnetic recording medium according to claim 13.

15. A surface treatment device that has a function of forming an activated gas by generating plasma by applying an electric field between opposing electrodes under pressure in a vicinity of atmospheric pressure, and radiating the activated gas onto surface of a substrate to be treated in which at least a magnetic layer and a protective film layer are formed on a non-magnetic substrate.

FIG. 1

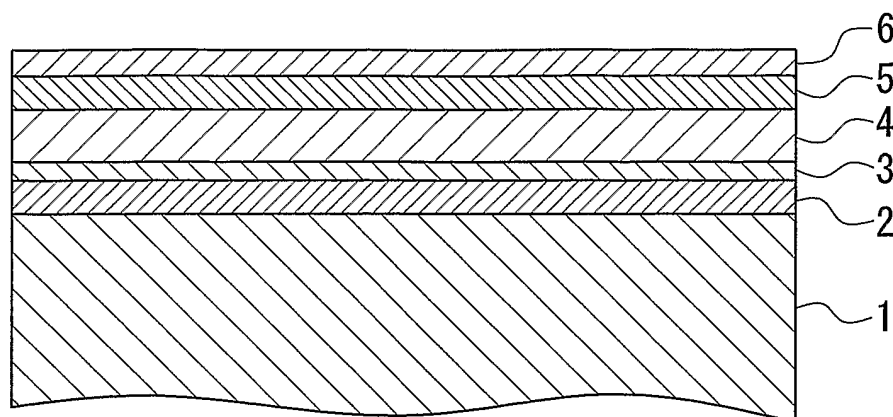


FIG. 2

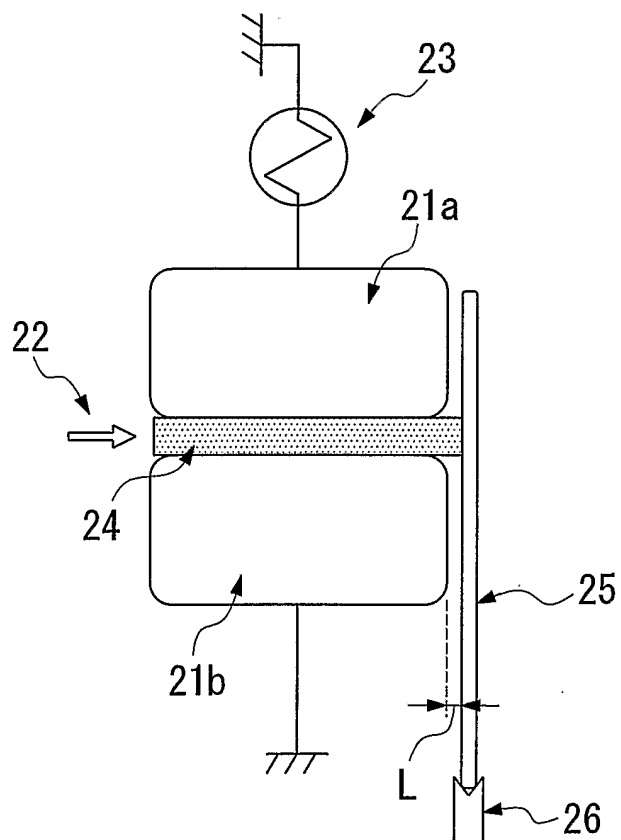


FIG. 3

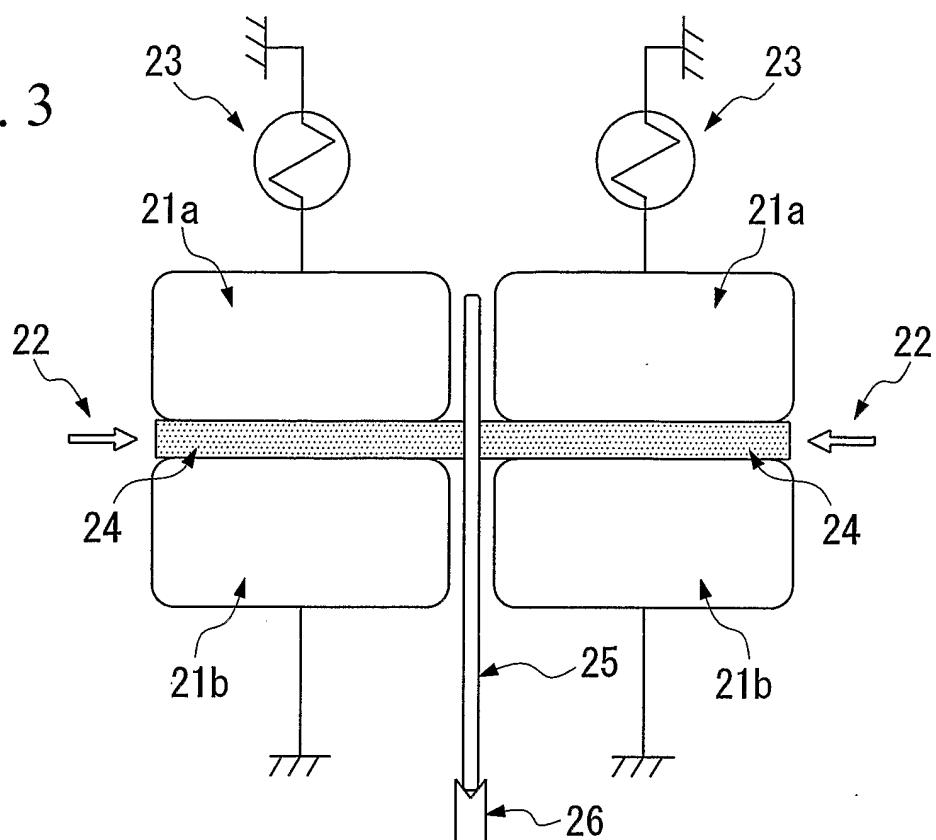


FIG. 4

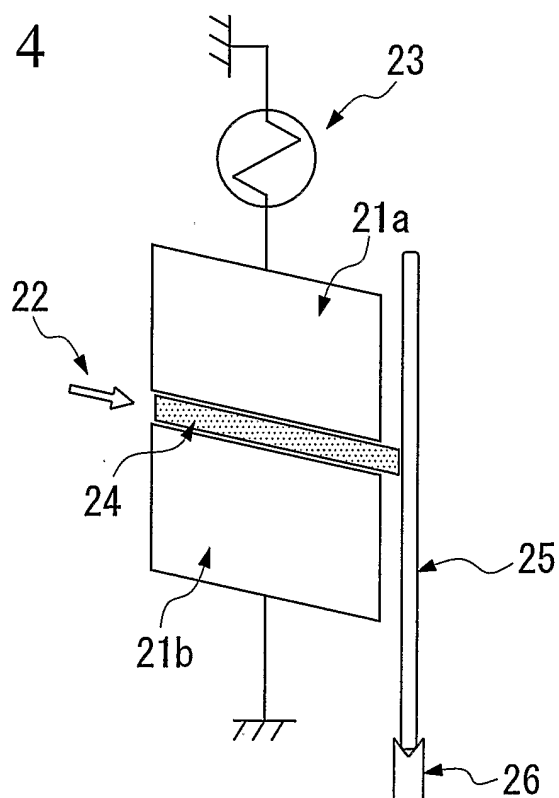


FIG. 5

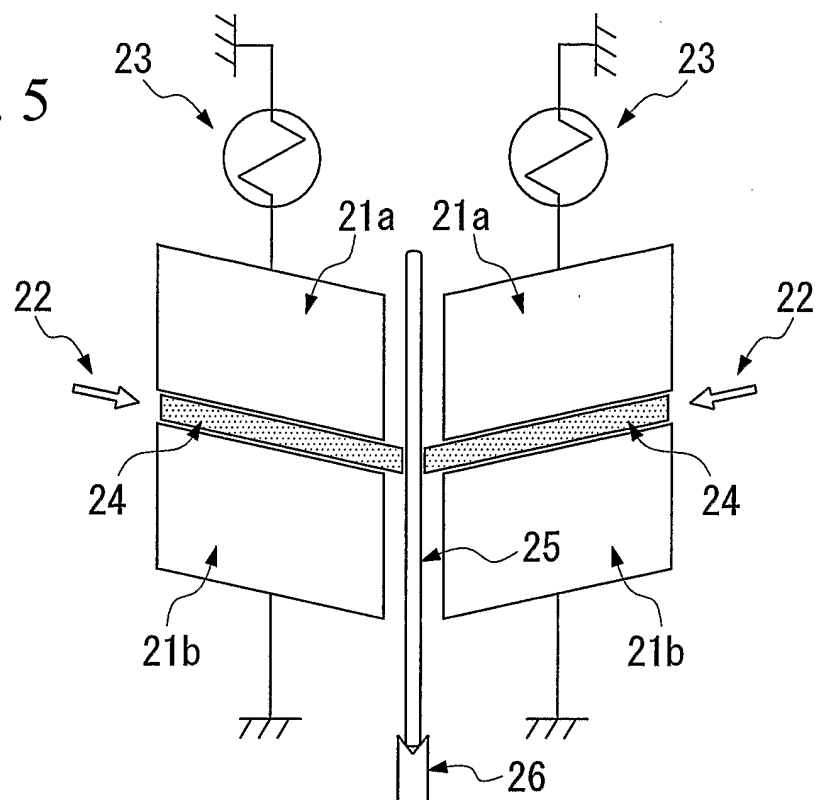
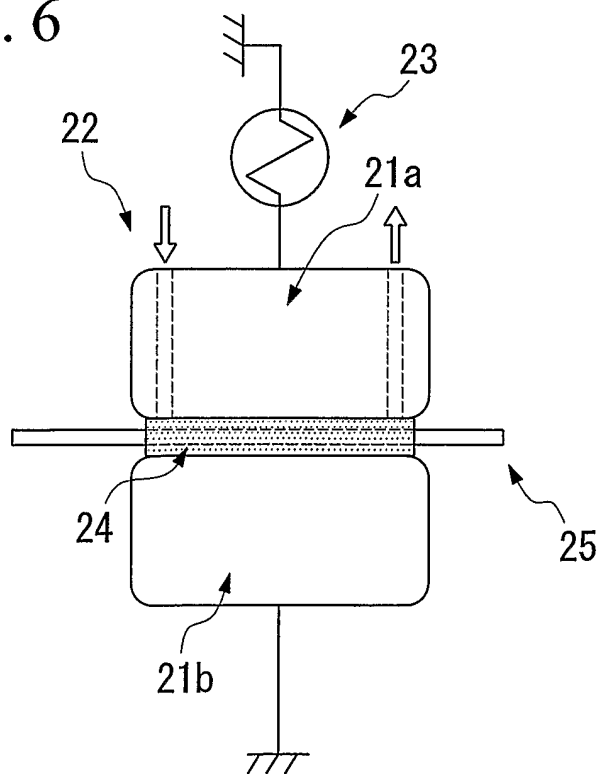


FIG. 6



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2005/015304

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. **G11B5/84** (2006.01), **G11B5/72** (2006.01), **C23C16/26** (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl. **G11B5/84** (2006.01), **G11B5/72** (2006.01), **C23C16/26** (2006.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
 Published unexamined utility model applications of Japan 1971-2005
 Registered utility model specifications of Japan 1996-2005
 Published registered utility model applications of Japan 1994-2005

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2000-176362 A (konika k.k.) 27Jun.2000 (27.06.00) paragraph46 (no family)	1-15
X	JP 2002-109721 A (konika k.k.) 12Apr.2002 (12.04.02) claim4, paragraph42 (no family)	1-15

☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

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Date of mailing of the international search report

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