DESCRIPTION

MAGNETIC RECORDING MEDIUM

TECHNICAL FIELD

[0001] The present invention relates to a magnetic recording medium ~~and a manufacturing method thereof~~, and more particularly to a magnetic recording medium suitable for external storage devices of computers and a manufacturing method thereof. More specifically, the present invention relates to a magnetic recording medium which has a lubricating layer including a perfluoropolyether compound having a perfluorotrimethyleneoxy repeating unit in the main chain and a cyclic triphosphazene structure and which makes it possible to reduce the head levitation amount ~~flying height~~, and also to a manufacturing method thereof. The present invention also relates to a method for reducing the head levitation amount ~~flying height~~ and improving the electromagnetic conversion property of a magnetic recording medium by changing the mixing ratio of the perfluoropolyether compound in the lubricating layer.

BACKGROUND ART

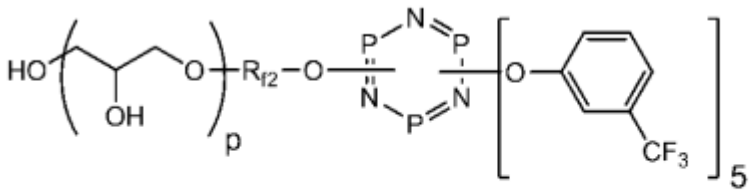
[0002] In order to improve durability and reliability of a magnetic recording medium (in particular, a magnetic disk) and ~~also~~ to reduce a friction force generated between the

protective layer of the magnetic recording medium and the head, it is necessary to impart a lubricating property to the

magnetic recording medium. For example, a lubricating property has been improved by forming a lubricating layer including a perfluoropolyether lubricant having a polar end group such as a hydroxyl group in a molecule on a diamond-like carbon (DLC) film that is typically used as a protective layer for magnetic recording media.

[0003] Further, ~~WO 2007/043450 describes the feature of forming~~ it has been suggested to form a lubricating layer by using a perfluoropolyether lubricant represented by Formula (V) and has ~~having~~ a cyclic triphosphazene structure in a molecule with the object ~~objective~~ of increasing ~~improving~~ the adhesion to a magnetic recording medium and reducing decomposition ability (see Patent Document 1). ~~Further, WO 2006/009057 describes the feature of forming~~ It has also been suggested to form a lubricating layer by using a mixture of a compound with p = 1 and a compound with p = 2 in Formula (V) (see Patent Document 2). ~~WO 2008/140121 describes the feature of forming~~ Furthermore, it has also been suggested to form a lubricating layer by using a perfluoropolyether lubricant having a cyclic triphosphazene structure with a different number of perfluoropolyether side chains (see Patent Document 3).

[0004] [C 1]



(V)

R_{f2} = $-CH_2CF_2O(CF_2CF_2O)_p(CF_2O)_qCF_2CH_2-$
p = 1-3

[0005] A lubricating layer formed on a protective layer is ~~can be assumed to be~~ constituted by two layers. The first layer is a layer bonded to the protective layer (referred to hereinbelow as "bonded lubricating layer"), and the other is a layer present on the bonded lubricating layer and not bonded to the protective layer (referred to hereinbelow as "free lubricating layer"). From the standpoint of improving the properties, it is preferred that the lubricating layer ~~have a structure with~~ be constituted by a thin free lubricating layer and a thick bonded lubricating layer.

[0006] However, following recent trend to increase in density of magnetic recording media (magnetic disks), more stringent requirements have been placed on the lubricant properties. In order to meet such requirements, it is important to ensure compatibility of heads and magnetic disks, and a lubricant material is needed that will make it possible to bring the head close to the magnetic disk (to reduce the head levitation amount ~~flying height~~).

[0007] In addition, the number of cases in which the recently developed hard disk drives are used not only for personal computers that are used indoors, but also in outdoor environment such as portable devices and car navigation systems, has grown. When the hard disk drive is used in an outdoor environment, in particular, a high-temperature and high-humidity environment, such environment makes it difficult for a magnetic head slider to levitate. This problem is

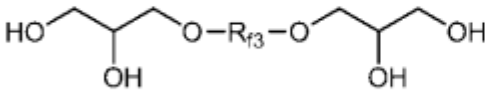
apparently attributable to cohesion of moisture contained in high-humidity air. Therefore, the problem of disposing a lubricant more accurately on the surface of a magnetic recording medium (magnetic disk) used in a hard disk drive is of major importance.

[0008] In order to solve this problem, it is important to reduce the ~~height~~ size of the molecule and control the orientation of the lubricant on the protective film. Fomblin (trade name) Z-dol (Formula (III)) and Fomblin (trade name) Z-tetraol (Formula (IV)) lubricants, which are presently typically used for magnetic recording media, are perfluoropolyether compounds having a hydroxyl group at either end (in the formulas, p and q are integers equal to or greater than 0, but the case in which p = q = 0 is excluded).

[0009] [C 2]



(III)



(IV)

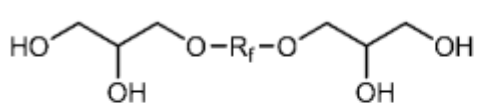
$$R_{f3} = -CH_2CF_2O(CF_2CF_2O)_p(CF_2O)_qCF_2CH_2-$$

[0010] The specific feature of the compound represented by Formula (III) and/or Formula (IV) is that when a lubricating layer is formed by coating on a protective layer, C, F, and O contained in the molecular structure are arranged randomly. This specific feature is affected by the molecular structure

(hydroxyl group present at each end) represented by Formula (III) or Formula (IV). Due to random arrangement, active oxygen atoms face the head side (front surface side), rather than the protective layer side. As a result, the adsorption of contaminating substances is enhanced and the adsorptivity on the head slider surface is increased. Such phenomena cause a variation in head levitating~~flying~~ property.

[0011] Therefore, in order to decrease the head levitation amount ~~flying height~~ and improve the levitation ~~flying~~ stability, a lubrication material is needed that has a chemical structure different from that represented by Formula (III) and/or Formula (IV). In this regard, ~~IEEE Transactions on Magnetics, "Lubricant Pickup of Ultra-Thin PFPE Lubricants with Different Backbone Structures", Vol. 47, No. 7, July, 2011, pp. 1837-1841, reports (see Non-Patent Document 1)~~it is reported that a lubricant pickup by the head is different when a lubricant is used that has the structure represented by Formula (I) which has a different main-chain repeating unit (see Non-Patent Document 1).

[0012] [C 3]



(I)

$R_f = -CH_2CF_2CF_2O(CF_2CF_2CF_2O)_mCF_2CF_2CH_2-$

[0013] ~~In the case of conventional lubricant containing the compound represented by Formula (III) and/or Formula (IV), the~~

The head levitating~~flying~~ property has been improved by optimizing the

additive to be added and the mixing ratio thereof, the total film thickness of the lubricating layer, and the ~~bonded~~ bond ratio in the conventional lubricant containing the compound represented by Formula (III) and/or Formula (IV). However, the problem is that when such means as the decrease in the total film thickness and/or increase in the ~~bonded~~bond ratio is used to improve the head levitating ~~flying~~ property, other properties (durability and the like) of the magnetic recording medium (in particular, the lubricating layer) are degraded.

[0014] Patent Document 1: WO 2007/043450

Patent Document 2: WO 2006/009057

Patent Document 3: WO 2008/140121

[0015] Non-Patent Document 1: IEEE Transactions on Magnetics, "Lubricant Pickup of Ultra-Thin PFPE Lubricants with Different Backbone Structures", Vol. 47, No. 7, July, 2011, pp. 1837-1841

DISCLOSURE OF THE INVENTION

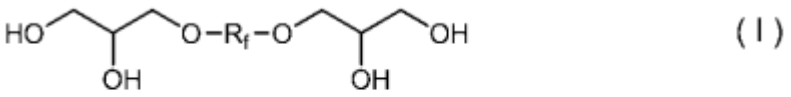
[0016] An objective of the present invention is to provide a magnetic recording medium that can realize high electromagnetic conversion property by reducing the head levitation amount~~flying height~~, without degrading other properties, and also to provide a manufacturing method thereof.

[0017] A magnetic recording medium according to the first embodiment of the present invention comprises~~has~~ an

underlayer, a magnetic layer, a protective layer, and a lubricating layer on a nonmagnetic substrate, wherein the protective layer includes

lubricating layer by laminating, on the protective layer, a mixture of a lubricant represented by Formula (I)

[C 6]

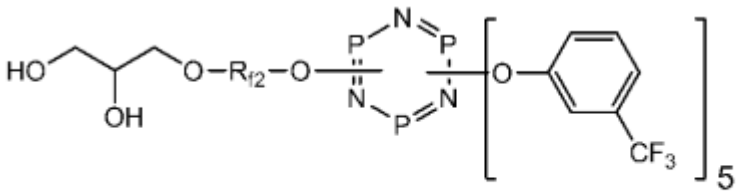


(I)

$R_f = -CH_2CF_2CF_2O(CF_2CF_2CF_2O)_mCF_2CF_2CH_2-$

(in the formula, m is an integer equal to or greater than 1), and a lubricant represented by Formula (II)

[C 7]



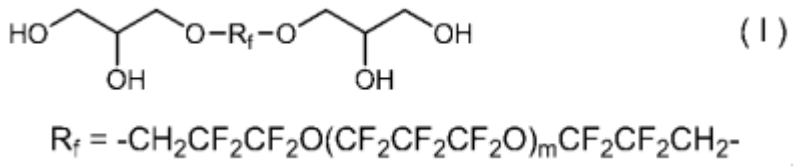
(II)

$R_{f2} = -CH_2CF_2O(CF_2CF_2O)_p(CF_2O)_qCF_2CH_2-$

(in the formula, p and q are integers equal to or greater than 0; the case in which p = q = 0 is excluded).

[0019] A method according to the third embodiment of the present invention is a method for reducing a levitation amount~~flying height~~ of a head and improving an electromagnetic conversion property in a magnetic recording medium that includes an underlayer, a magnetic layer, a protective layer including carbon, and a lubricating layer on a nonmagnetic substrate, the lubricating layer being constituted by a mixture of a lubricant represented by Formula (I)

[C 8]

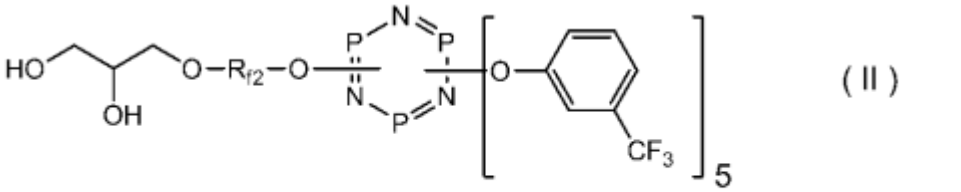


(I)

$R_f = -CH_2CF_2CF_2O(CF_2CF_2CF_2O)_mCF_2CF_2CH_2-$

(in the formula, m is an integer equal to or greater than 1), and a lubricant represented by Formula (II)

[C 9]



(II)

$R_{f2} = -CH_2CF_2O(CF_2CF_2O)_p(CF_2O)_qCF_2CH_2-$

(in the formula, p and q are integers equal to or greater than 0; the case in which p = q = 0 is excluded), the method including a step of changing a usage amount of the lubricant represented by Formula (I) and/or a mixing ratio of the lubricant represented by Formula (I) and the lubricant represented by Formula (II).

[0020] In the magnetic recording medium in accordance with the present invention, a lubricating layer constituted by a mixture of a compound represented by Formula (I) that includes a $-(CF_2CF_2CF_2O)_m-$ structure in the main chain and the compound represented by Formula (II) is provided instead of the lubricating layer including a generally used lubricant having a $-(CF_2CF_2O)_m(CF_2O)_n-$ structure in the main chain, thereby

making it possible to reduce the head levitation amount~~flying height~~ and

realize the magnetic recording medium surface with high durability. ~~Further,~~ I~~i~~t is found out that this effect is made more prominent by setting the added amount of the compound represented by Formula (II) (see Patent Documents 1 and 2) correspondingly~~equivalent~~ to the film thickness of 0 Å to 3 Å. By reducing the head levitation amount~~flying height~~, it is possible to improve the electromagnetic conversion property of the magnetic recording medium.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] FIG. 1 is a schematic diagram of a device for evaluating the head levitation amount~~flying height~~ of a magnetic recording medium.

FIG. 2 is a graph showing the relationship between the added amount of ADOH and the head levitation amount~~flying height~~ in Example 1, Comparative Example 1, and Comparative Example 2.

FIG. 3 is a schematic diagram of a device for evaluating the head levitation amount~~flying height~~ of a magnetic recording medium.

FIG. 4 is a graph showing the relationship between the added amount of ADOH and the TD power in Example 1, Comparative Example 1, and Comparative Example 2.

FIG. 5 is a schematic diagram of a device for evaluating the durability of a magnetic recording medium.

FIG. 6 is a graph illustrating a criterion for determining a breaking point.

FIG. 7 is a graph showing the relationship between the added amount of ADOH and the breaking point in Example 1, Comparative Example 1, and Comparative Example 2.

BEST MODE FOR CARRYING OUT THE INVENTION

[0022] The magnetic recording medium according to the first embodiment of the present invention includes a non-magnetic substrate, an underlayer, a magnetic layer, a protective layer including carbon, and a lubricating layer.

[0023] Various substrates with a smooth surface that are known in the related art can be used as the non-magnetic substrate. For example, a NiP-plated Al alloy (Al-Mg or the like), reinforced glass, and crystallized glass, which are used in the conventional magnetic recording media, can be used as the non-magnetic substrate.

[0024] In the present invention, the underlayer may be a soft magnetic layer for concentrating a magnetic flux generated by the head in the magnetic layer when vertical~~perpendicular~~ magnetic recording is performed, an intermediate layer for forming a magnetic layer having good magnetic properties by controlling the orientation of the magnetic layer, a seed layer for improving the orientation ability and adhesivity of the interlayer~~intermediate layer~~, or a laminated structure thereof.

[0025] A soft magnetic underlayer can be formed by using a crystalline material such as FeTaC and Sendust (FeSiAl) alloy,

or an amorphous material including a Co alloy such as CoZrNb and CoTaZr.

[0026] The interlayer~~intermediate layer~~ is used for controlling the crystal grain size and crystal orientation of the magnetic layer and preventing magnetic coupling of~~between~~ the soft ~~magnetic~~ underlayer (when such is present) and the magnetic layer. Therefore, it is preferred that the interlayer~~intermediate layer~~ be nonmagnetic. The crystal structure of the interlayer~~intermediate layer~~ is ~~appropriately~~ selected, as appropriate, according to the material of the magnetic layer. For example, when the magnetic layer positioned directly thereabove is formed from a material based on Co and having a hexagonal closely packed (hcp) structure, the interlayer~~intermediate layer~~ can be formed using a material having a hcp or a face-centered cubic (fcc) structure. Alternatively, the interlayer~~intermediate layer~~ can be made to ~~may~~ have a non-crystalline structure. Examples of the preferred materials for forming the interlayer~~intermediate layer~~ include Ru, Re, Rh, Pt, Pd, Ir, Ni, Co, and alloys thereof.

[0027] The seed layer is used with the object of ensuring adhesion between the interlayer~~intermediate layer~~ and the non-magnetic substrate or soft magnetic underlayer (when such is present) and controlling the orientation of the interlayer~~intermediate layer~~. The seed layer can be formed using NiW, Ta, Cr, or an alloy including Ta and/or Cr. The

seed layer may also have a layered structure constituted by a plurality of layers including the aforementioned material.

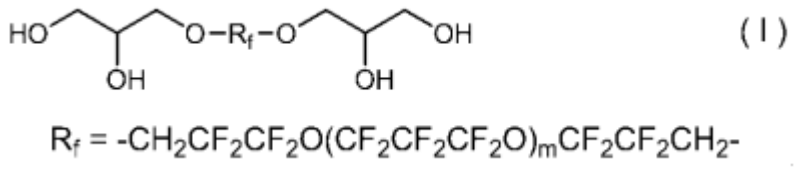
[0028] In the present invention, the magnetic layer can be formed using a crystalline magnetic material. The crystalline magnetic materials that can be used include ferromagnetic materials such as alloys including at least Co and~~or~~ Pt (for example, Co-Cr-Ta, Co-Cr-Pt). In this case, the axis of easy magnetization of the ferromagnetic material should be oriented in the direction in which magnetic recording is performed. In order to perform vertical~~perpendicular~~ magnetic recording, the axis of each~~easy~~ magnetization of the material of the magnetic layer (c-axis of the hcp structure) should be oriented in the direction perpendicular to the surface of the magnetic recording medium (that is, to the main plane of the non-magnetic substrate). Alternatively, the magnetic layer may have a structure (the so-called granular structure) in which magnetic crystal grains are separated by a non-magnetic body ~~(the so-called granular structure)~~. In this case, it is preferred that the magnetic crystal grains have a columnar shape with a diameter of several nanometers. It is preferred that the non-magnetic body have a subnanometer thickness. The materials for forming magnetic crystal grains include alloys based on magnetic elements such as Co, Fe, and Ni. It is preferred that materials for forming the magnetic crystal grains include materials obtained by adding a metal such as Cr, B, Ta, and W to a CoPt alloy. Meanwhile, the materials for forming the non-magnetic body include oxides or nitrides of Si, Cr, Co, Ti, or Ta.

[0029] In the present invention, the carbon materials for forming the protective layer include amorphous carbon and diamond-like carbon (DLC).

[0030] The underlayer, magnetic layer, and protective layer including carbon are formed using means typically used in the related art.

[0031] The lubricating layer of the magnetic recording medium in accordance with the present invention can be formed using a mixture of a lubricant represented by Formula (I)

[C 10]

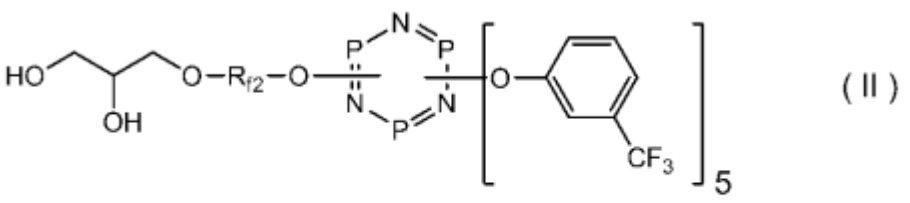


(I)

$R_f = -CH_2CF_2CF_2O(CF_2CF_2CF_2O)_mCF_2CF_2CH_2-$

(in the formula, m is an integer equal to or greater than 1), which includes a perfluorotrimethylene repeating unit ($-CF_2CF_2CF_2O-$) in the main chain and has a hydroxyl group (–OH) at each end, and a lubricant represented by Formula (II)

[C 11]



(II)

$R_{f2} = -CH_2CF_2O(CF_2CF_2O)_p(CF_2O)_qCF_2CH_2-$

(in the formula, p and q are integers equal to or greater than 0; the case in which p = q = 0 is excluded). D4OH (manufactured by MORESCO), which is described in Non-Patent Document 1~~As~~ ,is an example of

the lubricant represented by Formula (I) ~~includes D4OH (manufactured by MORESCO), which is described in Non-Patent Document 1~~. ADOH (manufactured by MORESCO) is ~~As~~ an example of the lubricant represented by Formula (II) ~~includes~~ ~~ADOH (manufactured by MORESCO)~~.

[0032] The lubricating layer of the magnetic recording medium in accordance with the present invention is desirably constituted only by the mixture of the lubricant represented by Formula (I) and the lubricant represented by Formula (II). In this case the added amount of the lubricant represented by Formula (II) is desirably set correspondingly~~equivalent~~ to a film thickness of 0.3 Å to 3 Å.

[0033] The lubricating layer of the magnetic recording medium in accordance with the present invention can be formed by a coating method using a solution including, as a solid component, a mixture of the lubricant represented by Formula (I) and the lubricant represented by Formula (II). The coating method can be a dipping method. Post-treatment such as UV treatment and tape varnish treatment may be implemented after the lubricating layer has been formed.

[0034] The magnetic recording medium in accordance with the present invention will be explained below in greater detail on the basis of examples therefor. However, the present invention is not limited to the below-described examples and can be variously changed without departing from the essence thereof.

Examples

[0035] (Example 1)

A magnetic disk substrate with a diameter of 65 mm that was covered with a protective layer of diamond-like (diamond-shaped) carbon with a thickness of 2.0 nm was fabricated by a plasma CVD method. A mixture of D4OH represented by Formula (I) and ADOH represented by Formula (II) was dissolved in a Vertrel XF (manufactured by Du Pont-Mitsui Fluorochemicals Co., Ltd.) solvent, and a lubricating layer coating liquid was produced. A magnetic disk substrate was immersed into the lubricating layer coating solution, pulled up at a rate of 1.5 mm/sec and then dried. The dry coating film was then UV treated using a UV lamp with an emission peak wavelength of 185 nm/254 nm and an output of 200 W and the lubricating layer was formed. In this case, the concentration of D4OH in the lubricating layer coating liquid containing only D4OH and the concentration of D4OH and ADOH in the lubricating layer coating liquid using the mixture were adjusted such that the total film thickness of the obtained lubricating layer was 7 Å to 10 Å and the film thickness of ADOH, which was an additive, was 0.3 Å to 3.0 Å. Further, the lubricating layer was formed such that the thickness of the bonded Å ~~lubricant~~ was about 6.00 Å and the bond~~bonded~~ ratio was 75.0%.

[0036] The "total film thickness of the lubricating layer" in the present invention is the thickness of the lubricating layer at the time the lubricating layer is formed, and it is measured with a Fourier transform IR spectrophotometer(FT-IR).

The "film thickness of the bonded lubricating layer" in the present invention is the thickness of the layer of the lubricant that is actually bonded to the carbon surface of the protective layer~~. More specifically, the "film thickness of the bonded lubricating layer"~~ , which is the thickness of the lubricating layer after the obtained lubricating layer has been washed using Vertrel XF (manufactured by Du Pont-Mitsui Fluorochemicals Co., Ltd.), and it is measured with a Fourier transform IR spectrophotometer (FT-IR).

[0037] The degree of bonding of a lubricant with functional groups present on the carbon surface of a protective layer is typically represented by the ratio of the lubricating layer thickness after washing with a fluorine-containing solvent to the lubricating layer thickness prior to washing with the fluorine-containing solvent, and the percentage value thereof is called "bond~~ed~~ ratio". In the present invention, the "bond~~ed~~ ratio" is determined by the following formula by using the film thickness prior to washing with the aforementioned Vertrel XF (manufactured by Du Pont-Mitsui Fluorochemicals Co., Ltd.) (that is, the total film thickness of the lubricating layer) to the film thickness after the washing (that is, the film thickness of the bonded lubricating layer).

[0038] [Math. 1]

Bond~~ed~~ ratio (%) = [(Film thickness of lubricating layer after washing)/(Film thickness of lubricating layer prior to washing)] × 100

[0039] (Comparative Example 1)

A lubricating layer was formed by repeating the procedure of Example 1, except that the lubricating layer coating liquid was formed using a mixture of Fomblin (trade name) Z-tetraol (Formula (IV)) and ADOH. The concentrations of the Fomblin (trade name) Z-tetraol and ADOH in the coating liquid were adjusted such that the total film thickness of the obtained lubricating layer was 8.0 Å and the film thickness of ADOH, which was the additive, was 2.0 Å. Further, the lubricating layer was formed such that the thickness of the bonded lubricating layer was about 6.00 Å and the bond~~ed~~ ratio was 75.0%.

[0040] (Comparative Example 2)

A lubricating layer was formed by repeating the procedure of Example 1, except that ADOH was not used. The concentrations of the D4OH in the coating liquid were adjusted such that the total film thickness of the obtained lubricating layer was 9.0 Å. Further, the lubricating layer was formed such that the thickness of the bonded lubricating layer was about 6.00 Å and the bond~~ed~~ ratio was 75.0%.

[0041] (Evaluation)

(1. Low flying levitation amount~~height~~ property)

A levitation~~flying height~~ limit was measured using RQ7800 (manufactured by Hitachi) which is shown schematically in FIG.

1. Initially, a magnetic recording medium 1 having a lubricating layer formed thereon was mounted on a spindle

motor 12 mounted on a support section 11. Then, the magnetic recording medium 1 was rotated and a ~~30% size~~ glide head 15 and a PZT sensor 16 (manufactured by GW Co.) taking 30% of ~~at~~ the distal end ~~of~~ an arm 14 attached to an arm support section 13 were caused to levitate~~take off~~ above the magnetic recording medium. In this state, the circumferential speed of the glide head 15 was gradually decreased by controlling the spindle motor, and the circumferential speed at which the glide head 15 dropped down was measured and ~~then~~ determined as a levitation~~flying height~~ limit. The results obtained are shown in Table 1 and FIG. 2.

[0042] Table 1

Evaluation of levitation amount~~flying height~~

	Lubricant material	Total film thickness (Å)	ADOH film thickness (Å)	Flying height limit (mm)
Comparative Example 1	Fomblin Z-tetraol + ADOH	8.29	2.31	2.41
Comparative Example 2	D4OH	9.21	0.00	2.33
Example 1	D4OH + ADOH	9.07	0.32	2.33
	D4OH + ADOH	8.48	0.79	2.33
	D4OH + ADOH	8.72	1.43	2.33
	D4OH + ADOH	9.08	3.02	2.33
	D4OH + ADOH	7.49	1.51	2.32
	D4OH + ADOH	7.69	2.86	2.32
	D4OH + ADOH	9.42	1.48	2.36
	D4OH + ADOH	6.51	1.46	2.29
	D4OH + ADOH	6.11	3.05	2.29

[0043] The levitation~~flying height~~ limit value obtained for the sample of Comparative Example 2 that used D4OH including a $-(CF_2CF_2CF_2O)_m-$ structure in the main chain and the sample of Example 1 using the mixture of D4OH and ADOH was lower than that obtained for the sample of Comparative Example 1 using Fomblin (trade name) Z-tetraol including a $-(CF_2CF_2O)_m(CF_2O)_n-$

structure in the main chain. The dependence of the

levitation~~flying~~

~~ height~~ limit value on the added amount of ADOH, which was an additive, and the dependence of the levitation~~flying height~~ limit value on the total film thickness of the lubricating layer were not observed. However, as a result of using D4OH or the mixture of D4OH and ADOH, the levitation~~flying height~~ limit value was improved by about 2% to about 5%.

[0044] (2. Low-height levitation amount~~flying height~~ property)

~~As shown schematically in FIG. 3, by using VENA manufactured by VENA Co., a~~ A program head 25 was heated with a heater ~~(not shown in the figure)~~, the element portion of the head was thermally expanded, and the element portion of the program head 25 was caused to protrude till the element portion came into contact with the magnetic recording medium 1 by using VENA manufactured by VENA Co. and shown schematically in FIG.3. The protrusion of the element portion reduced the distance (levitation amount~~flying height~~) between the program head 25 and the magnetic recording medium 1. Stable levitation~~flying~~ of the program head 25 above the lubrication~~lubricating~~ layer was maintained even when the protrusion of the element portion increased. A test was conducted by using drive conditions such as the revolution speed of the magnetic recording medium and the initial (when no power was applied) head levitation amount~~flying height~~ as the HDD usage conditions. A contact point was detected with an acoustic emission (AE) sensor 26 at the attachment portion

of the program head 25, and the power applied at this time (touchdown power, TD power) was taken as an indicator of the low-height levitation~~flying height~~ property. ~~Where~~ As the detection of the contact is

delayed more(TD power is larger), ~~a larger amount of power can be applied~~ application to the heater is made more possible and the protrusion amount of the element portion increases. Therefore, the distance between the program head 25 and the magnetic recording medium is decreased and low-height levitation~~flying height~~ is made possible. The results obtained are shown in Table 2 and FIG. 4.

[0045] Table 2

Evaluation of flying height

	Lubricant material	Total film thickness (Å)	ADOH film thickness (Å)	TD power (mV)
Comparative Example 1	Fomblin Z-tetraol + ADOH	8.29	2.31	42.39
Comparative Example 2	D4OH	9.21	0.00	47.32
Example 1	D4OH + ADOH	9.07	0.32	48.65
	D4OH + ADOH	8.48	0.79	48.79
	D4OH + ADOH	8.72	1.43	47.27
	D4OH + ADOH	9.08	3.02	46.65
	D4OH + ADOH	7.49	1.51	47.63
	D4OH + ADOH	7.69	2.86	47.17
	D4OH + ADOH	9.42	1.48	47.11
	D4OH + ADOH	6.51	1.46	49.19
	D4OH + ADOH	6.11	3.05	48.51

[0046] The results ~~in Table 2 and FIG. 4~~ obtained indicate that the power that can be applied to the heater heating the head in

the case of the mixed sample of D4OH and ADOH is larger than that in the case of a mixed sample of Fomblin (trade name) Z-tetraol and ADOH of Comparative Example 1. The dependence of the~~TD~~ power on the total film thickness was observed, and the amount of power that could be applied to the heater increased advantageously with the decrease in film thickness. Further, ~~good result was obtained in the samples where~~ since the added amount of ADOH was small, good result was obtained.

[0047] (3. Durability characteristic)

Durability was evaluated by using a friction player (FPR-2100) manufactured by RHESCA and shown schematically in FIG. 5. The evaluation method is called POD. Thus, a~~A~~ load of 30 gf (about 0.29 N) was applied to an Al_2O_3-TiC ball 35 (disposed at the distal end of an arm 34 mounted on an arm support section 33) brought into contact with the magnetic recording medium 1, the magnetic recording medium 1 was rotated by using a spindle motor 32 mounted on a support section 31, the ball 35 was moved at a circumferential speed of 25 mm/s, and a break~~ing~~ point of the lubricating layer was observed. More specifically, a friction coefficient between the magnetic recording medium 1 and the ball 35 was measured with a load cell 36 mounted on the arm 33, and the number of cycles at a point of time in which a rapid change (breakage~~breaking~~ sign 61) in the friction coefficient was observed~~occurred~~, as shown in FIG. 6, was taken as a breaking point 62. In this

evaluation, it can be determined that good lubricating layer with high durability is

obtained when the appearance of the breaking point 62 is delayed. The results obtained are shown in Table 3 and FIG. 7.

[0048] Table 3

Evaluation of flying height

	Lubricant material	Total film thickness (Å)	ADOH film thickness (Å)	Breaking point (cycles)
Comparative Example 1	Fomblin Z-tetraol + ADOH	8.29	2.31	284.5
Comparative Example 2	D4OH	9.21	0.00	266.2
Example 1	D4OH + ADOH	9.07	0.32	350.8
	D4OH + ADOH	8.48	0.79	420.1
	D4OH + ADOH	8.72	1.43	526.0
	D4OH + ADOH	9.08	3.02	600.1
	D4OH + ADOH	7.49	1.51	458.6
	D4OH + ADOH	7.69	2.86	510.3
	D4OH + ADOH	9.42	1.48	607.2
	D4OH + ADOH	6.51	1.46	414.6
	D4OH + ADOH	6.11	3.05	430.2

[0049] The results ~~in Table 3 and FIG. 7~~ indicate that the mixed sample of D4OH and ADOH of Example 1 had a ~~higher~~ breaking point and durability ~~is~~ higher than those of the mixed sample of Fomblin (trade name) Z-tetraol and ADOH of Comparative Example 1. Further, the comparison of the mixed

sample of D4OH and ADOH of Example 1 and the D4OH sample of Comparative Example 2 demonstrated that the addition of ADOH is effective in terms of improving durability. Further, the comparison of the samples of Example 1 demonstrates that durability increases with the increase in the added amount of ADOH. The comparison of the samples of Example 1 also indicates that durability depends on the total film thickness and increases with the increase in total film thickness.

[0050] The above-described results demonstrate that the lubricating layer in accordance with the present invention that is constituted by a mixture of D4OH having the structure represented by Formula (1) and ADOH having the structure represented by Formula (II) makes it possible to reduce the head levitation amount~~flying height~~ by comparison with that of the lubricating layer constituted by the generally used mixture of Fomblin (trade name) Z-tetraol and ADOH. Therefore, it is apparent that the lubricating layer in accordance with the present invention is extremely effective means for reducing a gap between a head and a magnetic recording medium and providing a magnetic recording medium having a better electromagnetic conversion property. Furthermore, it is determined that durability of the lubricating layer is greatly increased by the addition of ADOH by comparison with that in the case in which only D4OH is used. Thus, it is clear that by optimizing the added amount of ADOH it is possible to decrease the head levitation

amount~~flying height~~ and increase durability of the lubricating layer.

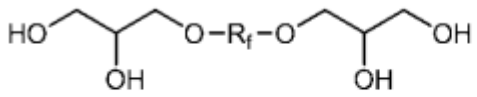
a step of forming an underlayer on a non-magnetic substrate;

a step of laminating a magnetic layer on the underlayer;

a step of laminating a protective layer including carbon on the magnetic layer; and

a step of forming a lubricating layer by laminating, on the protective layer, a mixture of a lubricant represented by Formula (I)

[C 3]

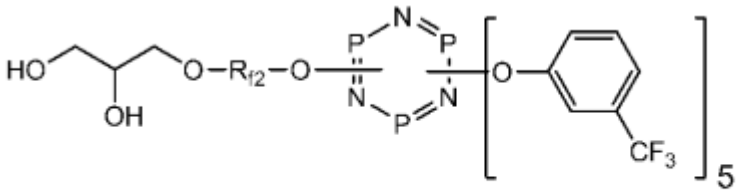


(I)

$R_f = -CH_2CF_2CF_2O(CF_2CF_2CF_2O)_mCF_2CF_2CH_2-$

(in the formula, m is an integer equal to or greater than 1), and a lubricant represented by Formula (II)

[C 4]



(II)

$R_{f2} = -CH_2CF_2O(CF_2CF_2O)_p(CF_2O)_qCF_2CH_2-$

(in the formula, p and q are integers equal to or greater than 0; the case in which p = q = 0 is excluded).

3. A method for reducing a levitation amount~~flying height~~ of a head and improving an electromagnetic conversion

property in a magnetic recording medium that includes an underlayer, a magnetic layer,