

METHOD FOR PRODUCING MAGNETIC RECORDING MEDIUM AND PROTECTIVE
FILM THEREOF

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present disclosure relates to a method for producing a magnetic recording medium and a protective film that is suitable for producing a magnetic recording medium.

2. Description of the Related Art

In order to improve the recording density of a hard disk drive (HDD), not only is it necessary to improve its magnetic recording layer, but also the distance between the magnetic recording layer and a magnetic head for reading/writing information (magnetic spacing) needs to be reduced. Therefore, there has been used ~~technologies~~ technology such that reduces the thickness of a protective film formed on the magnetic recording layer, reduces the thickness of a lubricating film formed on the protective film, reduces the flying height of the magnetic head, and technology known as a flying on demand (FOD) which causes a read/write element part of the magnetic head to protrude to reduce the effective flying height.

Among all these technologies, reducing the thickness of the protective film in the magnetic recording medium is quite important. Japanese Patent Application Publication No. 2010-205323 proposes a technology for reducing the thickness of a protective film.

SUMMARY OF THE INVENTION

However, the recent protective films need to be reduced in thickness and be able to further adapt to the FOD and other technologies by improving the bonding with lubricating layers.

the step (b-1) being performed by the plasma CVD method using a source gas in which a mixture ratio between the lower saturated hydrocarbon gas and the lower unsaturated hydrocarbon gas is adjusted such that the average number of hydrogen atoms per carbon atom in the source gas ~~becomes~~ is greater than 2.5 but less than 3.0, and

the step (b-2) being performed by the plasma CVD method using a source gas in which a mixture ratio between the lower saturated hydrocarbon gas and the lower unsaturated hydrocarbon gas is adjusted such that the average number of hydrogen atoms per carbon atom in the source gas ~~becomes~~ is greater than 2.0 but less than 2.5.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A. Method for producing a protective film, which can be used for producing a magnetic recording medium

The method for producing a protective film according to the invention of the present application, which can be used for producing a magnetic recording medium, has the steps of:

(a) providing the magnetic layer formed on the substrate;
and

(b) forming the protective film on the magnetic layer by means of a plasma CVD method using mixed gas of lower saturated hydrocarbon gas and lower unsaturated hydrocarbon gas as source gas.

(1) Step (a)

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The magnetic layer on which the protective film is formed is provided by the step (a).

(1-1)

The magnetic layer is formed on the substrate. The substrate is preferably non-magnetic and can be made of any material that has conventionally been used in

The average number of hydrogen atoms N per carbon atom in the source gas can be calculated using the following formula where N_H^i represents the number of hydrogen atoms ~~per carbon atom~~ in a molecule of each hydrocarbon gas i , N_C^i represents the number of carbon atoms in a molecule of each hydrocarbon gas i , and F^i represents the flow rate (sccm) of each the hydrocarbon gas i :

$$N = \frac{(\sum N_H^i \times F^i)}{(\sum F^i)} \quad N = \frac{\sum (N_H^i \times F^i)}{\sum (N_C^i \times F^i)}$$

In this formula, Σ denotes the sum of each hydrocarbon gas i .

In the step (b-1), the source gas having the mixture ratio in which the average number of hydrogen atoms per carbon atom is relatively high is used, so that more of the tetrahedral structure resulting from C-H bonding is introduced into the obtained first protective film, improving the corrosion resistance/durability of the magnetic recording medium.

In the step (b-2), on the other hand, the use of the source gas having the mixture ratio in which the average number of hydrogen atoms per carbon atom is relatively low, can reduce the amount of hydrogen (H) component in the obtained second protective film that interferes with the bonding between the lubricating layer and the protective film, improving the FOD performance.

In the step (b-1), the average number of hydrogen atoms per carbon atom in the source gas is set to be greater than

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2.5, based on the technical aspect of introducing more of the tetrahedral structure resulting from C-H bonding. Moreover, the average number of hydrogen atoms per carbon atom in the source gas is set to be less than 3.0, based on the technical aspect of preventing polymerization that results from excess hydrogen.

film and excellent FOD performance of the second protective film.

(3) Step (c)

Step (c) may include a step of further nitriding a surface of the protective film obtained in the step (b).

This step can introduce a nitrogen (N) component for facilitating the bonding between the surface of the protective film and the lubricating layer, further improving the FOD performance.

Introducing the nitrogen (N) component can be performed by introducing nitrogen gas into, for example, a plasma source and subjecting a surface of a carbon layer to nitrogen plasma processing.

B. Method for producing a magnetic recording medium

Subsequent to A. Method for producing a protective film, which is described above, a magnetic recording medium can be produced by forming the lubricating layer on the protective film. The resultant magnetic recording medium has at least a substrate, a magnetic layer formed on the substrate, a protective film formed on the magnetic layer, and a lubricating layer formed on the protective film.

The lubricating layer is a layer for providing lubricity between the magnetic head and the magnetic recording medium. The lubricating layer can be formed on the substrate by using a liquid lubricant known in the technical field. Specifically, it is preferred to use perfluoropolyether liquid lubricant

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(PFPE). The liquid lubricant can be applied to the lubricant layer to a thickness of approximately 1 nm by means of a dip coating method or spin coating method. Specific examples of the liquid lubricant include Fomblin-Z-tetraol (manufactured by Solvay Solexis) and A20H (manufactured by MORESCO).

element part of the magnetic head was switched on to thermally expand the read/write element part of the magnetic head and to gradually protrude the read/write element part. Then, touch-down (TD) heater power was measured at which the flying magnetic head ~~goes~~ becomes unstable. The TD was detected using an acoustic emission (AE) sensor at a rotation speed of 7200 rpm. The TD heater power was as large as 50.7 mW, which was a good result.

The TD heater power equal to or greater than 50.0 mW was evaluated as "particularly" good and set as a reference criterion. This value indicates the level at which the effect of FOD can be seen in the magnetic recording properties of the magnetic recording medium.

[Examples 2 to 9]

~~A-m~~ Magnetic recording media were prepared using the same method as Example 1, on condition that the mixture ratio between ethane (C_2H_6) gas and ethylene (C_2H_4) gas used in the first formation step of a protective film was changed variously. The other conditions are the same as those of Example 1. In other words, the substrate, magnetic layer, second protective film, and lubricating layer are the same in Examples 1 to 9.

The results of evaluations of corrosion resistance and durability of these magnetic recording media are shown in Table 1 along with the evaluation results obtained in Example 1.

The condition in which the mixture ratio between ethylene (C_2H_4) gas and ethane (C_2H_6) gas used in the second formation step of a protective film was changed variously was implemented using the same method as in Example 1. The other conditions are the same as those of Example 1. In other words, the substrate, magnetic layer, first protective film, and lubricating layer are the same in Examples 1 and 10 to 17.

The results of the FOD performance of these magnetic recording media are shown in Table 2 along with the results obtained in Example 1.

(Table 2) The flow rates of the source gas in the second step and the results of evaluations of the FOD performance of the example magnetic recording media

	Source gas			Evaluation of FOD performance
	Ethane gas flow rate	Ethylene gas flow rate	Average number of hydrogen atoms per carbon atom	
Example 1	15 sccm	45 sccm	2.25	50.7 mW
Example 10	15 sccm	30 sccm	2.33	50.4 mW
Example 11	15 sccm	15 sccm	2.50	49.5 mW
Example 12	30 sccm	45 sccm	2.40	50.1 mW
Example 13	30 sccm	30 sccm	2.50	49.0 mW
Example 14	30 sccm	15 sccm	2.67	48.6 mW
Example 15	45 sccm	45 sccm	2.50	48.7 mW
Example 16	45 sccm	30 sccm	2.60	47.9 mW
Example 17	45 sccm	15 sccm	2.75	46.8 mW

As is clear from the evaluation results shown in Table 2 above, when the flow rate of the ethylene (C_2H_4) gas was greater than the flow rate of the ethane (C_2H_6) gas and the average number of hydrogen atoms per carbon atom in the source gas was greater than 2.0 but less than 2.5, excellent FOD performance (equal to or greater than 50.0 mW) ~~were~~ was obtained (Examples 1, 10, 12).

However, when the flow rate of the ethylene (C_2H_4) gas was lower than the flow rate of the ethane (C_2H_6) gas and the average number of hydrogen atoms per carbon atom in the source gas was equal to or greater than 2.5 but

CLAIMS

1. A method for producing a protective film, which can be used for producing a magnetic recording medium having a substrate, a magnetic layer formed on the substrate, a protective film formed on the magnetic layer, and a lubricating layer formed on the protective film, the method comprising the steps of:

(a) providing the magnetic layer formed on the substrate;
and

(b) forming the protective film on the magnetic layer by means of a plasma CVD method using mixed gas of lower saturated hydrocarbon gas and lower unsaturated hydrocarbon gas as source gas,

wherein the lower saturated hydrocarbon gas is selected from the group consisting of methane, ethane, propane, butane, and a mixture of two or more thereof,

the lower unsaturated hydrocarbon gas is selected from the group consisting of ethylene, propylene, butylene, butadiene, and a mixture of two or more thereof, and

the step (b) includes a step (b-1) of forming a first protective film on the magnetic layer and a step (b-2) of forming a second protective film on the first protective film,

the step (b-1) being performed by the plasma CVD method using a source gas in which a mixture ratio between the lower saturated hydrocarbon gas and the lower unsaturated

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hydrocarbon gas is adjusted such that the average number of hydrogen atoms per carbon atom in the source gas ~~becomes~~ is greater than 2.5 but less than 3.0, and

the step (b-2) being performed by the plasma CVD method using a source gas in which a mixture ratio between the lower saturated hydrocarbon gas and the lower unsaturated hydrocarbon gas is adjusted such that the average number of hydrogen atoms per carbon atom in the source gas ~~becomes~~ is greater than 2.0 but less than 2.5.

2. The method for producing a protective film according to claim 1, wherein the lower saturated hydrocarbon gas is ethane and the lower unsaturated hydrocarbon gas is ethylene.

3. The method for producing a protective film according to claim 1, wherein a potential difference for ion acceleration applied by the plasma CVD method in the step (b-1) is equal to or lower than 180 V, and a potential difference for ion acceleration applied by the plasma CVD method in the step (b-2) is equal to or greater than 180 V.

4. The method for producing a protective film according to claim 1, further comprising, subsequent to the step (b), a step (c) of nitriding a surface of the protective film.

5. A method for producing a magnetic recording medium comprising the method for producing a protective film according to any one of claims 1 to 4.