

PLASMA CVD APPARATUS, METHOD FOR MANUFACTURING MAGNETIC
RECORDING MEDIUM AND METHOD FOR DEPOSITING FILM

BACKGROUND OF THE INVENTION

5 Field of the Invention

[0001]

The present invention relates to a plasma CVD apparatus,
a method for manufacturing a magnetic recording medium and
a method for depositing a film.

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Background Art

[0002]

In Japanese Patent Laid-Open Publication No.
2000-226657 (Patent Document 1), there is disclosed a hot
15 filament plasma chemical vapor deposition (CVD) apparatus
in which a film is deposited simultaneously on each of both
surfaces of a disk substrate that is a medium for a Hard Disk
Drive (HDD). In this hot filament plasma CVD apparatus,
since plasma is generated for both surfaces of a disk
20 substrate, plasma for one surface interferes with plasma for
the other surface and thickness distribution of a film
deposited on the disk substrate may be deteriorated.
Accordingly, it was difficult to deposit a film having good
thickness uniformity on a disk substrate.

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Description of a Related Art

Patent Document

[0003]

[Patent Document 1] Japanese Patent Laid-Open
Publication No. 2000-226657

5 SUMMARY OF THE INVENTION

[0004]

An aspect of the present invention aims at providing
a plasma CVD apparatus, a method for manufacturing a magnetic
recording medium or a method for depositing film that can
10 deposit a film having good thickness uniformity on a
substrate to be deposited.

[0005]

Hereinafter, various aspects of the present invention
will be described.

15 [1] A plasma CVD apparatus, including:

a chamber;

a holding part that holds a substrate to be deposited
arranged inside the chamber;

a first direct-current power source connected
20 electrically with the holding part;

a first anode arranged inside the chamber and arranged
on one side of the holding part;

a first cathode arranged inside the chamber and
arranged on one side of the holding part;

25 a second direct-current power source connected
electrically with the first anode;

a first alternating-current power source connected

electrically with the first cathode;

a gas supply mechanism that supplies raw material gas to the inside of the chamber;

an evacuation mechanism for evacuating the inside of
5 the chamber; and

a control part that controls the first direct-current power source so as to apply a first voltage to the holding part in a pulse form of a cycle not less than 1/100 msec and not more than 1 msec (frequency of not less than 1 kHz and
10 not more than 100 kHz) and a DUTY cycle of not less than 10% and not more than 90%.

[0006]

[2] The plasma CVD apparatus according to [1], wherein the control part controls the first direct-current
15 power source so as to apply a second voltage to the holding part in a period during which the first voltage is not applied to the holding part (remaining period of a DUTY cycle of not less than 10% and not more than 90% in the cycle); and

the second voltage is a voltage whose positive and
20 negative are opposite to those of the first voltage.

[0007]

[3] The plasma CVD apparatus according to [2], wherein an absolute value of the second voltage lies in a range not less than 10% and not more than 60% (preferably not less
25 than 20% and not more than 50%) of an absolute value of the first voltage.

[0008]

[4] The plasma CVD apparatus according to any one of [1] to [3], further including a plasma wall that is arranged inside the chamber, is provided so as to cover each of spaces between the substrate to be deposited held by the holding part, and the first anode and the first cathode, and is set as a floating potential.

[0009]

[5] The plasma CVD apparatus according to any one of [1] to [4], further including:

10 a second anode that is arranged inside the chamber and is arranged on the other side of the holding part;

 a second cathode that is arranged inside the chamber and is arranged on the other side of the holding part;

 a third direct-current power source connected
15 electrically with the second anode; and

 a second alternating-current power source connected electrically with the second cathode.

[0010]

[6] A method for manufacturing a magnetic recording
20 medium using a plasma CVD apparatus according to any one of [1] to [4], including:

 holding a substrate to be deposited on which at least a magnetic layer is formed on a nonmagnetic substrate by the holding part; and

25 making the raw material gas into a plasma state by discharge between the first cathode and the first anode inside the chamber, and causing this plasma to accelerate

and collide with a surface of the substrate to be deposited held by the holding part to form a protective film containing carbon as a main component.

[0011]

5 [7] A method for depositing a film on a substrate to be deposited using a plasma CVD apparatus having a holding part that holds a substrate to be deposited, an anode and a cathode that are arranged inside a chamber, including:

 arranging the substrate to be deposited so as to face
10 the anode and the cathode inside the chamber; and

 supplying raw material gas into the chamber, and applying a first direct-current voltage to the anode, and applying an alternating voltage to the cathode, and

 making the raw material gas into a plasma state by
15 applying a second direct-current voltage to the holding part in a pulse form of a cycle of not less than 1/100 msec and not more than 1 msec (frequency of not less than 1 kHz and not more than 100 kHz) and a DUTY cycle of not less than 10% and not more than 90% inside the chamber, and causing the
20 plasma to accelerate and collide with the substrate to be deposited to form a film.

[0012]

 [8] The method for depositing a film according to [7], wherein:

25 in a period during which the second direct-current voltage is not applied to the holding part, a third direct-current voltage is applied to the holding part; and

the third direct-current voltage is a voltage whose positive and negative are opposite to those of the second direct-current voltage.

[0013]

5 [9] The method for depositing a film according to [8] wherein

an absolute value of the third direct-current voltage lies in a range of not less than 10% and not more than 60% (preferably not less than 20% and not more than 50%) of an
10 absolute value of the second direct-current voltage.

[10] The method for depositing a film according to any one of [7] to [9], wherein

a current value flowing to the substrate to be deposited when the film is deposited onto the substrate to be deposited
15 is not less than 1.2 times a current value that corresponds to the DUTY cycle of a current value flowing to the substrate to be deposited in a case where the second direct-current voltage is continuously applied to the holding part.

[0014]

20 [11] A method for manufacturing a magnetic recording medium on which a protective film is formed containing carbon as a main component after the step of forming at least a magnetic layer on a nonmagnetic substrate, wherein

the protective film is formed by the method for
25 depositing a film according to any one of [7] to [10].

[0015]

According to an aspect of the present invention, it

is possible to provide a plasma CVD apparatus, a method for manufacturing a magnetic recording medium or a method for depositing a film that can deposit a film having good thickness uniformity on a substrate to be deposited.

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BRIEF DESCRIPTION OF THE DRAWINGS

[0016]

FIG. 1 is a cross-sectional view showing schematically a plasma CVD apparatus according to an aspect of the present invention.

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FIG. 2 is a view for explaining a period of applying each of a second and third direct-current voltage.

FIG. 3 is a cross-sectional view for explaining a method for manufacturing a magnetic recording medium using the plasma CVD apparatus shown in FIG. 1.

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FIG. 4 is a view showing appearance photographs of samples (1) - (6) in Examples and an appearance photograph of a sample in Comparative Example when each DLC film was deposited on a substrate to be deposited using the plasma CVD apparatus shown in FIG. 1.

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DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0017]

Hereinafter, embodiments of the present invention will be described in detail through the use of the drawings. However, a person skilled in the art would easily understand that the present invention is not limited to the following

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explanation, but forms and details thereof can be variously modified without deviating from the purport and the scope of the present invention. Accordingly, the present invention is not to be construed as being limited to
5 description of the embodiments shown below.

[0018]

<Plasma CVD apparatus>

FIG. 1 is a cross-sectional view showing schematically a plasma CVD apparatus according to an aspect of the present
10 invention. This plasma CVD apparatus has a right-left symmetrical structure relative to a substrate to be deposited (for example, a disk substrate) 1, and is an apparatus capable of depositing simultaneously a film on each of both surfaces of the substrate to be deposited 1.

15 [0019]

The plasma CVD apparatus has a chamber 102, and inside the chamber 102, there are formed first and second cathode electrodes (first and second cathode filaments) 103a and 103b in a filament shape, for example, made of tantalum. Both ends
20 of each of the first and second cathode filaments 103a and 103b are connected electrically with first and second cathode power sources (first and second alternating-current power sources) 105a and 105b lying outside the chamber 102, and the first and second cathode power sources 105a and 105b are
25 arranged in a state insulated against the chamber 102. As the first and second cathode power sources 105a and 105b, for example, a power source of 0 to 50 V and 10 to 50 A (ampere)

can be used. One end of each of the first and second cathode power sources 105a and 105b is connected electrically with a ground 106.

[0020]

5 Inside the chamber 102, first and second anode electrodes (first and second anode cones) 104a and 104b having a funnel-like shape are arranged so as to surround each of the first and second cathode filaments 103a and 103b, and each of the first and second anode cones 104a and 104b
10 is formed in a speaker-like shape.

[0021]

 The first anode cone 104a is connected electrically with a first anode power source (first DC power source) 107a via a first switch 121a, and the first DC power source 107a
15 is arranged in a state insulated against the chamber 102. The plus potential side of the first DC power source (also called a second direct-current power source) 107a is connected electrically with the first anode cone 104a via the first switch 121a, and the minus potential side of the
20 first DC power source 107a is connected electrically with the ground 106.

[0022]

 The second anode cone 104b is connected electrically with a second anode power source (second DC power source)
25 107b via a second switch 121b, and the second DC power source 107b is arranged in a state insulated against the chamber 102. The plus potential side of the second DC power source

(also called a third direct-current power source) 107b is connected electrically with the second anode cone 104b via the second switch 121b, and the minus potential side of the second DC power source 107b is connected electrically with
5 the ground 106.

[0023]

Each of the first and second switches 121a and 121b and each of the first and second DC power sources 107a and 107b are controlled by a non-illustrated control part.
10 Consequently, a voltage to be applied to each of the first and second anode cones 104a and 104b is controlled. Meanwhile, as the first and second DC power sources 107a and 107b, for example, a power source of 0 to 500 V and 0 to 7.5 A (ampere) can be used.

15 [0024]

Inside the chamber 102, the substrate to be deposited
1 is arranged, and this substrate to be deposited 1 is arranged so as to face the first and second cathode filaments 103a and 103b and the first and second anode cones 104a and 104b.
20 In detail, the first and second cathode filaments 103a and 103b are surrounded by the vicinity of the center portion of the inner peripheral surface of the first and second anode cones 104a and 104b, and the first and second anode cones 104a and 104b are arranged in a state where the largest inside
25 diameter sides thereof face the substrate to be deposited 1.

[0025]

It is so configured that the substrate to be deposited 1 is supplied sequentially to an illustrated position with a non-illustrated holding part and a non-illustrated transfer apparatus (handling robot or a rotary index table).

5 [0026]

The substrate to be deposited 1 is connected electrically with a bias power source (DC power source) 112 as a power source for ion acceleration, and this DC power source 112 is arranged in an insulated state against the
10 chamber 102. The minus potential side of this DC power source 112 is connected electrically with the substrate to be deposited 1, and the plus potential side of the DC power source 112 is connected electrically with the ground 106. As the DC power source 112, for example, a power source of 0 to 1500
15 V and 0 to 100 mA (milliampere) can be used.

[0027]

Inside the chamber 102, a first plasma wall 108a is arranged so as to cover spaces between each of the first cathode filament 103a and the first anode cone 104a, and the
20 substrate to be deposited 1, and a second plasma wall 108b is arranged so as to cover spaces between each of the second cathode filament 103b and the second anode cone 104b, and the substrate to be deposited 1.

[0028]

25 Each of the first and second plasma walls 108a and 108b is connected electrically with a floating potential (not illustrated), and is arranged in an insulated state against

the chamber 102. Moreover, the first and second plasma walls 108a and 108b have a cylindrical shape or a polygonal shape.

[0029]

For an end part of each of the first and second plasma
5 walls 108a and 108b on the substrate to be deposited 1 side,
film thickness compensation plates 118a and 118b are provided,
and the film thickness compensation plates 118a and 118b are
connected electrically with the floating potential. By
means of the film thickness compensation plates 118a and 118b,
10 thickness of a film to be deposited in an outer periphery
part of the substrate to be deposited 1 can be controlled.

[0030]

Outside the chamber 102, first and second neodymium
magnets 109a and 109b are arranged. The first and second
15 neodymium magnets 109a and 109b have, for example, a
cylindrical or polygonal shape, in which the center of the
inside diameter of the cylindrical or polygonal shape becomes
the magnet center, and this magnet center lies so as to face
each of approximate centers of the first and second cathode
20 filaments 103a and 103b and an approximate center of the
substrate to be deposited 1. In each of the first and second
neodymium magnets 109a and 109b, the magnetic force at the
magnet center thereof is preferably not less than 50 G (gauss)
and not more than 200 G, more preferably not less than 50
25 G and not more than 150 G. The reason why the magnetic force
at the magnet center is limited to be not more than 200 G
is that, in a neodymium magnet, it is a limitation in

manufacturing to rise the magnetic force at the magnet center up to 200 G. Moreover, the reason why the magnetic force at the magnet center is preferably set to be not more than 150 G is that cost for fabricating a magnet increases when the magnetic force at the magnet center exceeds 150 G.

[0031]

The plasma CVD apparatus has additionally a vacuum evacuation mechanism (not illustrated) for vacuum evacuating the inside of the chamber 102. Moreover, the plasma CVD apparatus has a gas supply mechanism (not illustrated) for supplying deposition raw material gas to the inside of the chamber 102.

[0032]

The bias power source (also called a first direct-current power source) 112 is controlled by a control part 130, and a voltage applied to the substrate to be deposited 1 via the holding part is controlled as follows.

The bias power source 112 is controlled so as to apply a second direct-current voltage (also called a first voltage) to the holding part, in a pulse form of a cycle of not less than 1/100 msec and not more than 1 msec (frequency of not less than 1 kHz and not more than 100 kHz) and a DUTY cycle of not less than 10% and not more than 90% (preferably not less than 30% and not more than 90%, more preferably not less than 30% and not more than 80%, furthermore preferably not less than 50% and not more than 80%). Consequently, the above-described second direct-current voltage is supplied

to the substrate to be deposited 1 via the holding part.

[0033]

Further, the bias power source 112 is controlled so as to apply a third direct-current voltage (also called a
5 second voltage) to the holding part in a period during which the second direct-current voltage is not applied to the holding part (a remaining period of a DUTY cycle of not less than 10% and not more than 90% in the cycle). Consequently, the third direct-current voltage is applied to the substrate
10 to be deposited 1 via the holding part. Moreover, the third direct-current voltage may be a voltage in which plus and minus are reverse to those of the second direct-current voltage.

[0034]

15 The reason why the DUTY cycle is set to be not less than 10% is that, if a DUTY cycle is set to be less than 10%, a deposition rate (deposition speed of a film) becomes too late.

[0035]

20 Meanwhile, in this embodiment, it is set to be a cycle of not less than 1/100 msec and not more than 1 msec (frequency of not less than 1 kHz and not more than 100 kHz), but a cycle of not less than 1/50 msec and not more than 1/5 sec (frequency of not less than 5 kHz and not more than 50 kHz) is preferable,
25 a cycle of not less than 1/40 msec and not more than 1/5 msec (not less than 5 kHz and not more than 40 kHz) is more preferable, and a cycle of not less than 1/30 msec and not

more than 1/5 msec (frequency of not less than 5 kHz and not more than 30 kHz) is furthermore preferable.

[0036]

Moreover, in this embodiment, the second
5 direct-current voltage is supplied to the substrate to be deposited 1 via the holding part by the bias power source 112, but the second direct-current voltage may be supplied directly to the substrate to be deposited 1 by the bias power source 112.

10 [0037]

The DUTY cycle is a ratio of a period during which the second direct-current voltage is applied to the holding part in one cycle. For example, in a case where a DUTY cycle is 30%, a period of 30% in one cycle is a period during which
15 the second direct-current voltage is applied to the holding part, and a period of 70% in one cycle is a period during which the third direct-current voltage is applied to the holding part. In detail, for example, in a case of a cycle of 1 msec (frequency of 1 kHz) and a DUTY cycle of 30%, a
20 period of 0.3 msec, which is 30% of 1 msec (1 cycle), is a period during which the second direct-current voltage is applied, and a period of 0.7 msec, which is 70% of 1 msec (1 cycle), is a period during which the third direct-current voltage is applied.

25 [0038]

Moreover, for example FIG. 2 shows a case of a DUTY cycle of $100S/T\%$, in which a period of $100S/T\%$ in one cycle

is a period during which the second direct-current voltage (-x V) is applied, and a period of remaining 100N/T% in one cycle is a period during which the third direct-current voltage (y V) is applied. Here, x and y are positive numerical values.

[0039]

The absolute value of the third direct-current voltage may lie in a range of not less than 10% and not more than 60% (preferably not less than 20% and not more than 50%) of the absolute value of the second direct-current voltage.

[0040]

<Method for depositing film>

There is described a method for depositing a DLC film over the substrate to be deposited 1 using the plasma CVD apparatus shown in FIG. 1.

[0041]

First, the vacuum evacuation mechanism is started to make the inside of the the chamber 102 be a predetermined vacuum state, and for example toluene (C_7H_8) gas is introduced as a deposition raw material gas into the inside of the chamber 102 by the gas introduction mechanism. After the inside of the chamber 102 has reached a predetermined pressure, by supplying an alternating current to each of the first and second cathode filaments 103a and 103b by the first and second cathode power sources 105a and 105b, the first and second cathode filaments 103a and 103b are heated.

[0042]

Moreover, the first direct-current voltage is applied to each of the first and second anode cones 104a and 104b from each of the first and second DC power sources 107a and 107b via the first and second switches 121a and 121b. In addition, the second direct-current voltage is applied to the substrate to be deposited 1 by the bias power source 112 via the holding part. The second direct-current voltage (also called a first voltage) to be applied on this occasion is a direct-current voltage in a pulse shape of a cycle of not less than 1/100 msec and not more than 1 msec (frequency of not less than 1 kHz and not more than 100 kHz) and a DUTY cycle of not less than 10% and not more than 90% (preferably not less than 30% and not more than 90%, more preferably not less than 30% and not more than 80%, and furthermore preferably not less than 50% and not more than 80%), and is controlled by the above-described control part 130. Furthermore, the third direct-current voltage is applied to the substrate to be deposited 1 by the bias power source 112 via the holding part. The third direct-current voltage (also called a second voltage) to be applied on this occasion is a direct-current voltage in a pulse shape that is applied in a period during which the second direct-current voltage is not applied to the holding part (a remaining period of a DUTY cycle of not less than 10% and not more than 90% in the cycle), and is controlled by the above-described control part 130. It is suitable that the third direct-current voltage is a voltage in which plus and minus are reverse to

that of the second direct-current voltage, and that the absolute value of the third direct-current voltage lies in a range of not less than 10% and not more than 60% (preferably not less than 20% and not more than 50%) of the absolute value
5 of the second direct-current voltage. Meanwhile, in this method for depositing a film, the second direct-current voltage is a negative voltage (for example, -250 V), and the third direct-current voltage is a positive voltage (for example, +90 V).

10 [0043]

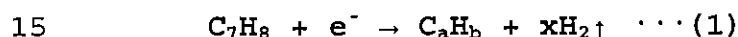
As a consequence of heating of the first and second cathode filaments 103a and 103b, a lot of electrons are ejected from each of the first and second cathode filaments 103a and 103b toward each of the first and second anode cones
15 104a and 104b to thereby start glow discharge between each of the first and second cathode filaments 103a and 103b and each of the first and second anode cones 104a and 104b. By a lot of electrons, the toluene gas as a deposition raw material gas lying inside the chamber 102 is ionized and
20 formed into a plasma state. On this occasion, a magnetic field is generated by each of the first and second neodymium magnets 109a and 109b in regions of forming toluene gas into plasma, which lie near each of the first and second cathode filaments 103a and 103b, and, therefore, the plasma can be
25 densified by the magnetic field and ionization efficiency can be improved. Then, deposition raw material molecules in a plasma state are directly accelerated by application of

the negative potential of the second direct-current voltage in a pulse form to the substrate to be deposited 1, travel toward the direction of the substrate to be deposited 1, and adhere over the surface of the substrate to be deposited 1.

5 Further, as a consequence of the application of the positive potential of the third direct-current voltage to the substrate to be deposited 1 in a period during which the second direct-current voltage is not applied, charges of the negative potential on the substrate to be deposited 1 are

10 surely cancelled. In this way, a thin DLC film is formed over the substrate to be deposited 1. On this occasion, a reaction according to Formula (1) below occurs over the surface of the substrate to be deposited 1.

[0044]



[0045]

<Method for manufacturing magnetic recording medium>

FIG. 3 is a cross-sectional view for explaining a method for manufacturing a magnetic recording medium using the

20 plasma CVD apparatus shown in FIG. 1, and shows a part of a magnetic recording medium. The magnetic recording medium is a medium, for example, for an HDD.

[0046]

First, a substrate to be deposited 1 including at least

25 a magnetic layer 12 on a nonmagnetic substrate 11 is prepared, and the substrate to be deposited 1 is held by the holding part. Subsequently, raw material gas (for example, toluene)

is made into a plasma state by discharge between each of the first and second cathode filaments 103a and 103b and each of the first and second anode cones 104a and 104b having been heated under a predetermined vacuum condition inside the chamber 102, and a second direct-current voltage (negative voltage) in a pulse form of a cycle of not less than 1/100 msec and not more than 1 msec (frequency of not less than 1 kHz and not more than 100 kHz) and a DUTY cycle of not less than 10% and not more than 90% is applied to the holding part by the bias power source 112. Further, in a period during which the second direct-current voltage is not applied to the holding part (remaining period of a DUTY cycle of not less than 10% and not more than 90% in the cycle), a third direct-current voltage (positive voltage) is applied to the holding part by the bias power source 112. Details are the same as the aforementioned method for depositing a film. In this way, this plasma is accelerated and caused to collide with the surface of the substrate to be deposited 1 held by the holding part. As a result, there is formed a DLC film 13 as a protective film containing carbon as a main component over the surface of this substrate to be deposited 1.

[0047]

According to the present embodiment, the second direct-current voltage in a pulse form of the above-described cycle and DUTY cycle is applied to the substrate to be deposited 1 by the bias power source 112 via the holding part, and the third direct-current voltage is applied in a period

during which the second direct-current voltage is not applied. Consequently, in the period during which the second direct-current voltage that is a negative voltage is applied to the substrate to be deposited 1, directional movement is generated in ions in a plasma state and a film is deposited over the substrate to be deposited 1, but, in the period during which the second direct-current voltage is not applied to the substrate to be deposited 1, the third direct-current voltage that is a positive voltage is applied to the substrate to be deposited 1 to thereby cancel surely charges of a negative voltage on the substrate to be deposited 1. That is, as a consequence of cancelling surely charges of a negative potential on the substrate to be deposited 1 in the period during which the second direct-current voltage is not applied to the substrate to be deposited 1, mutual interference of each plasma on one side and the other side of the substrate to be deposited 1 can be suppressed. As the result, it becomes possible to deposit the DLC film 13 having a thickness of good uniformity over the substrate to be deposited 1.

[Example]

[0048]

FIG. 4 illustrates appearance photographs of samples (1) to (6) in Examples and a sample in Comparative Example in which a DLC film is deposited over a substrate to be deposited using the plasma CVD apparatus shown in FIG. 1.

[0049]

Deposition conditions of the samples (1) to (6) in Example and the sample in Comparative Example are as follows.

[Deposition conditions of sample (1)]

Substrate to be deposited 1: NiP/Al disk

5 Deposition apparatus: plasma CVD apparatus shown in FIG. 1

Starting raw material: highly pure toluene (C_7H_8)

Raw material gas flow rate on left side in FIG. 1: 3.25
sccm

10 Raw material gas flow rate on right side in FIG. 1:
3.5 sccm

Pressure: 0.3 Pa

Deposition time: 2 sec

Cathode filament 103a, 103b: tungsten filament

15 Output of alternating-current power source 105a, 105b:
360 W

Current of anode power source 107a, 107b: 1650 mA

Voltage of anode power source 107a, 107b: 75 V

Second direct-current voltage of bias power source
20 112: -250 V

Third direct-current voltage of bias power source 112:
+90 V

Cycle in application of second direct-current voltage:
1/5 msec

25 Frequency in application of second direct-current
voltage: 5 kHz

DUTY cycle in application of second direct-current

voltage in a pulse form: 70%

Period during which third direct-current voltage is applied: period during which second direct-current voltage is not applied

5 External magnetic field: 50 G

[0050]

[Deposition conditions of sample (2)]

Cycle in application of second direct-current voltage:
1/10 msec

10 Frequency in application of second direct-current
voltage: 10 kHz

Note that deposition conditions of sample (2) other than the above-described conditions are the same as those of sample (1).

15 [0051]

[Deposition conditions of sample (3)]

Cycle in application of second direct-current voltage:
1/20 msec

20 Frequency in application of second direct-current
voltage: 20 kHz

Note that deposition conditions of sample (3) other than the above-described conditions are the same as those of sample (1).

[0052]

25 [Deposition conditions of sample (4)]

Cycle in application of second direct-current voltage:
1/30 msec

Frequency in application of second direct-current voltage: 30 kHz

DUTY cycle in application of second direct-current voltage in a pulse form: 50%

5 Note that deposition conditions of sample (4) other than the above-described conditions are the same as those of sample (1).

[0053]

[Deposition conditions of sample (5)]

10 Cycle in application of second direct-current voltage: 1/30 msec

Frequency in application of second direct-current voltage: 30 kHz

15 Note that deposition conditions of sample (5) other than the above-described conditions are the same as those of sample (1).

[0054]

[Deposition conditions of sample (6)]

20 Cycle in application of second direct-current voltage: 1/30 msec

Frequency in application of second direct-current voltage: 30 kHz

DUTY cycle in application of second direct-current voltage in a pulse form: 90%

25 Note that deposition conditions of sample (6) other than the above-described conditions are the same as those of sample (1).

[0055]

[Deposition conditions in Comparative Example]

Substrate to be deposited 1: NiP/Al disk

Deposition apparatus: plasma CVD apparatus shown in

5 FIG. 1

Starting raw material: highly pure toluene (C_7H_8)

Raw material gas flow rate on left side in FIG. 1: 3.25

sccm

Raw material gas flow rate on right side in FIG. 1:

10 3.5 sccm

Pressure: 0.3 Pa

Deposition time: 2 sec

Cathode filament 103a, 103b: tungsten filament

Output of alternating-current power source 105a, 105b:

15 360 W

Current of anode power source 107a, 107b: 1650 mA

Voltage of anode power source 107a, 107b: 75 V

Second direct-current voltage of bias power source

112: -250 V

20 Period during which second direct-current voltage is
applied: continuous (100%)

External magnetic field: 50 G

[0056]

Note that different points of deposition conditions
25 in Comparative Example from the deposition conditions of
sample (1) are that the second direct-current voltage is
applied continuously and the third direct-current voltage

is not applied.

[0057]

As shown in FIG. 4, it was confirmed that thickness uniformity of DLC films of samples (1) to (6) in Example was improved as compared with the sample in Comparative Example. Moreover, it was confirmed that thickness uniformity of DLC films of samples (1) to (5) in Example was improved more, and thickness uniformity of DLC films of samples (4) and (5) was furthermore improved.

10 [0058]

The current value of each sample shown in FIG. 4 is a current value flowing from the bias power source 112 to the substrate to be deposited 1 in film deposition. A current of 46 mA flowed to the sample in Comparative Example, and, in contrast, a current of 32 mA flowed to the sample (1) in Example, a current of 32 mA flowed to the sample (2) in Example, a current of 33 mA flowed to the sample (3) in Example, and a current of 42 mA flowed to the sample (6) in Example. It is known that, with respect to these samples, when the current value of the sample in Comparative Example in which the second direct-current voltage was applied continuously, namely 46 mA, is denoted by 100%, the current value of samples (1) to (3) in Example is approximately 70% of 46 mA (32.2 mA) and the current value of the sample (6) in Example is approximately 90% of 46 mA (41.4 mA).

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[0059]

On the other hand, the current value of the sample (4)

in Example was 37 mA that exceeded 50% of 46 mA (23 mA), and the current value of the sample (5) in Example was 50 mA that exceeded 70% of 46 mA (32.2 mA). From these, it is known that thickness uniformity of the DLC film becomes better in the case where the current value that flows to the substrate to be deposited 1 exceeds a current value corresponding to a DUTY cycle of a current value when the second direct-current voltage is applied continuously (preferably it is not less than 1.2 times the current value corresponding to the DUTY cycle, more preferably it is not less than 1.4 times). Note that "not less than 1.2 times" means "not less than 27.6 mA" when a current value corresponding to the DUTY cycle is 23 mA, and "not less than 1.4 times" means "not less than 32.2 mA" when a current value corresponding to the DUTY cycle is 23 mA.

[Description of Reference Symbols]

[0060]

- 1 substrate to be deposited
- 11 nonmagnetic substrate
- 20 12 magnetic layer
- 13 DLC film
- 102 chamber
- 103a first cathode electrode (first cathode filament)
- 103b second cathode electrode (second cathode filament)
- 25 104a first anode electrode (first anode cone)
- 104b second anode electrode (second anode cone)
- 105a first cathode power source (first alternating-current

- power source)
- 105b second cathode power source (second alternating-current power source)
- 106 ground
- 5 107a first anode power source (first DC power source, second direct-current power source)
- 107b second anode power source (second DC power source)
- 108a first plasma wall
- 108b second plasma wall
- 10 109a first neodymium magnet
- 109b second neodymium magnet
- 112 bias power source (DC power source, first direct-current power source)
- 118a, 118b film thickness compensation plate
- 15 121a first switch
- 121b second switch
- 130 control part

CLAIMS:

1. A plasma CVD apparatus, comprising:
 - a chamber;
 - 5 a holding part that holds a substrate to be deposited arranged inside said chamber;
 - a first direct-current power source connected electrically with said holding part;
 - a first anode arranged inside said chamber and arranged
 - 10 on one side of said holding part;
 - a first cathode arranged inside said chamber and arranged on one side of said holding part;
 - a second direct-current power source connected electrically with said first anode;
 - 15 a first alternating-current power source connected electrically with said first cathode;
 - a gas supply mechanism that supplies raw material gas to the inside of said chamber;
 - an evacuation mechanism for evacuating the inside of
 - 20 said chamber; and
 - a control part that controls said first direct-current power source so as to apply a first voltage to said holding part in a pulse form of a cycle not less than 1/100 msec and not more than 1 msec and a DUTY cycle of not less than 10%
 - 25 and not more than 90%.
2. The plasma CVD apparatus according to claim 1, wherein

said control part controls said first direct-current power source so as to apply a second voltage to said holding part in a period during which said first voltage is not applied to said holding part; and

5 said second voltage is a voltage whose positive and negative are opposite to those of said first voltage.

3. The plasma CVD apparatus according to claim 2, wherein
 an absolute value of said second voltage lies in a range
10 not less than 10% and not more than 60% of an absolute value
 of said first voltage.

4. The plasma CVD apparatus according to any one of claims
1 to 3, further comprising a plasma wall that is arranged
15 inside said chamber, is provided so as to cover each of spaces
 between said substrate to be deposited held by said holding
 part, and said first anode and said first cathode, and is
 set as a floating potential.

20 5. The plasma CVD apparatus according to any one of claims
1 to 4, further comprising:

 a second anode that is arranged inside said chamber
 and is arranged on the other side of said holding part;

 a second cathode that is arranged inside said chamber
25 and is arranged on the other side of said holding part;

 a third direct-current power source connected
 electrically with said second anode; and

a second alternating-current power source connected electrically with said second cathode.

6. A method for manufacturing a magnetic recording medium
5 using a plasma CVD apparatus according to any one of claims
1 to 4, comprising:

holding a substrate to be deposited on which at least
a magnetic layer is formed on a nonmagnetic substrate by said
holding part; and

10 making said raw material gas into a plasma state by
discharge between said first cathode and said first anode
inside said chamber, and causing this plasma to accelerate
and collide with a surface of the substrate to be deposited
held by said holding part to form a protective film containing
15 carbon as a main component.

7. A method for depositing a film on a substrate to be
deposited using a plasma CVD apparatus having a holding part
that holds a substrate to be deposited, an anode and a cathode
20 that are arranged inside a chamber, comprising:

arranging said substrate to be deposited so as to face
said anode and said cathode inside said chamber;

supplying raw material gas into said chamber, and
applying a first direct-current voltage to said anode, and
25 applying an alternating voltage to said cathode, and

making said raw material gas into a plasma state by
applying a second direct-current voltage to said holding part

in a pulse form of a cycle of not less than 1/100 msec and not more than 1 msec and a DUTY cycle of not less than 10% and not more than 90% inside said chamber, and causing the plasma to accelerate and collide with said substrate to be
5 deposited to form a film.

8. The method for depositing a film according to claim 7, wherein:

in a period during which said second direct-current
10 voltage is not applied to said holding part, a third direct-current voltage is applied to said holding part; and
said third direct-current voltage is a voltage whose positive and negative are opposite to those of said second direct-current voltage.

15

9. The method for depositing a film according to claim 8, wherein

an absolute value of said third direct-current voltage lies in a range of not less than 10% and not more than 60%
20 of an absolute value of said second direct-current voltage.

10. The method for depositing a film according to any one of claims 7 to 9, wherein

a current value flowing to said substrate to be
25 deposited when said film is deposited onto said substrate to be deposited is not less than 1.2 times a current value that corresponds to said DUTY cycle of a current value flowing

to said substrate to be deposited in a case where said second direct-current voltage is continuously applied to said holding part.

- 5 11. A method for manufacturing a magnetic recording medium on which a protective film is formed containing carbon as a main component after the step of forming at least a magnetic layer on a nonmagnetic substrate, wherein
- the protective film is formed by the method for
- 10 depositing a film according to any one of claims 7 to 10.