

DESCRIPTION

PLASMA CVD APPARATUS, MAGNETIC RECORDING MEDIUM AND METHOD
FOR MANUFACTURING THE SAME

5

TECHNICAL FIELD

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

10

BACKGROUND ART

Fig. 4(A) is a cross-sectional view showing schematically a conventional plasma CVD apparatus, and Fig. 4(B) is a drawing showing a cathode and an AC power supply viewed from the direction of an arrow shown in Fig. 4(A).

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The plasma CVD apparatus has a left-right symmetrical structure with respect to a substrate to be deposited (for example, a disc substrate) 101, and is an apparatus capable of deposition on both sides of the substrate to be deposited 101 simultaneously, but in Fig. 4(A), the left side relative to the substrate to be deposited 101 is shown, and the right side is omitted.

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The plasma CVD apparatus has a chamber 102, and, to the chamber 102, a gas introduction flange 115 is mounted. By the gas introduction flange 115 and the chamber 102, a film-forming chamber is formed. In the gas introduction flange 115, a hot cathode (a cathode electrode) 103 is formed.

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Both ends of the hot cathode 103 are electrically connected to an AC power supply 105 positioned outside the gas introduction flange 115. One end of the AC power supply 105 is electrically connected to an earth 106.

5 In the gas introduction flange 115, a disc-shaped cathode back board 111 is formed. This cathode back board 111 is positioned between the hot cathode 103 and the AC power supply 105, and is set to be at float potential. In addition, in the gas introduction flange 115, an anode 104 including
10 an anode cone 104a and an anode base 104b is disposed, and, between the anode cone 104a and the cathode back board 111, a gap 113 is provided.

 The anode base 104b is electrically connected to a DC power supply 107. The positive potential side of the DC power
15 supply 107 is electrically connected to the anode base 104b, and the negative potential side of the DC power supply 107 is electrically connected to the earth 106.

 In the chamber 102, the substrate to be deposited 101 is disposed. The substrate to be deposited 101 is
20 electrically connected to a DC power supply (a direct-current power supply) 112 as a power supply for accelerating ions. The negative potential side of the DC power supply 112 is electrically connected to the substrate to be deposited 101, and the positive potential side of the DC power supply 112
25 is electrically connected to the earth 106.

 In the gas introduction flange 115 and the chamber 102 which are connected to the earth, a plasma wall 108 is disposed

so as to cover spaces between each of the hot cathode 103 and the anode 104, and the substrate to be deposited 101. The plasma wall 108 is electrically connected to float potential (not shown). In addition, the plasma wall 108 has
5 a cylindrical shape. Between the plasma wall 108 and the anode cone 104a, a ring-shaped space 114 is provided, and the width of the space 114 is approximately 15 mm. Furthermore, outside the chamber 102, a magnet 109 is disposed.

10 Next, there will be described a method for depositing a DLC (Diamond Like Carbon) film on the substrate to be deposited 101 using the plasma CVD apparatus shown in Figs. 4(A) and 4(B).

15 First, the inside of the chamber 102 is put into a under a predetermined vacuum state, and, into the inside of the chamber 102, for example, toluene (C_7H_8) gas is introduced as a deposition raw material gas from a gas introduction part 115a of the gas introduction flange 115. After the inside of the chamber 102 reaches a predetermined pressure, by
20 supplying an alternating current to the hot cathode 103 by the AC power supply 105, the hot cathode 103 is heated. In addition, a direct current is supplied to the anode 104 by the DC power supply 107, and a direct current is supplied to the substrate to be deposited 101 by the DC power supply
25 112.

By heating the hot cathode 103, a large quantity of electrons are emitted from the hot cathode 103 toward the

anode cone 104a, and glow discharge is started between the hot cathode 103 and the anode cone 104a. By the large quantity of electrons, the toluene gas as a deposition raw material gas in the chamber 102 are ionized, and are put into a plasma state. At this time, a magnetic field is generated in a region for converting the toluene gas positioned near the hot cathode 103 into plasma by the magnet 109, and thus it is possible to densify the plasma by the magnetic field. Then, deposition raw material molecules in the plasma state are directly accelerated by negative potential of the substrate to be deposited 101 and fly toward the direction of the substrate to be deposited 101, and adhere onto the surface of the substrate to be deposited 101. Consequently, on the substrate to be deposited 101, a thin DLC film is formed (see, for example, Patent Document 1).

In the above-mentioned conventional plasma CVD apparatus, since the gap 113 exists between the cathode back board 111 and the anode cone 104a, when forming a DLC film on the substrate to be deposited 101, the generation of discharge may be performed at the back face of the anode cone 104a, to thereby lead to the adherence of a carbon film 110a. In addition, the generation of discharge may be performed in the space 114 between the plasma wall 108 and the anode cone 104a, to thereby lead to the adherence of a carbon film also on the wall surface surrounding the space 114. These carbon films 110a having adhered are peeled and accumulate between the anode base 104b and the gas introduction flange

115, and as a result, by particles 110b of the accumulated carbon film, the insulation performance between the anode 104 and the gas introduction flange 115 deteriorates and it becomes difficult to perform stable discharge. Furthermore, 5 when the carbon film 110a is peeled, the carbon film peeled may adhere to the substrate to be deposited 101 to generate failures.

In addition, since the electric power consumed by the discharge generated at the back face of the anode cone 104a 10 or in the space 114 is a loss that does not contribute to the deposition onto the substrate to be deposited 101, along with the lowering of energy to be used for the decomposition of a raw material gas by the loss of electric power, there is a risk of lowering the quality of the film to be deposited 15 on the substrate to be deposited 101.

BACKGROUND ART DOCUMENT

PATENT DOCUMENT

Patent Document 1: Japanese Patent Application Laid-Open No. 2010-7126

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DISCLOSURE OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

An aspect of the present invention has an object of providing a plasma CVD apparatus capable of suppressing the 25 generation of discharge at the back face of an anode, or a magnetic recording medium using the plasma CVD apparatus or a method for manufacturing the same.

MEANS FOR SOLVING THE PROBLEMS

An aspect of the present invention is a plasma CVD apparatus including:

a chamber;

5 a plasma wall that is disposed in the chamber and has a cylindrical shape or a polygonal cross-section with opened both ends;

a holding part that is disposed in the chamber and holds a substrate to be deposited disposed near the opening of one
10 end of the plasma wall;

an anode that is disposed in the chamber and is disposed so as to cover the opening of the other end of the plasma wall;

a filament-shaped cathode that is disposed in the
15 chamber, is disposed on an inner side of the anode and near the opening of the other end of the plasma wall, and is disposed facing the substrate to be deposited held by the holding part;

an AC power supply or a DC power supply which is disposed
20 outside the chamber, is electrically connected to one end of the cathode via a first wiring, and is electrically connected to the other end of the cathode via a second wiring;

a hole which is provided at the anode, and through which each of the first wiring and the second wiring passes;

25 a first DC power supply that is disposed outside the chamber and is electrically connected to the anode;

a second DC power supply that is disposed outside the

chamber and is electrically connected to the substrate to be deposited held by the holding part;

a gas supply mechanism supplying a raw material gas into the chamber; and

5 an exhaust mechanism exhausting the inside of the chamber.

According to the above-mentioned one aspect of the present invention, it is possible, by disposing the anode so as to cover the opening of the other end of the plasma wall, to provide the plasma CVD apparatus capable of suppressing the generation of discharge at the back face of the anode.

In addition, in one aspect of the present invention, it is preferable that the largest gap between the other end of the plasma wall and the anode is not more than 5 mm, and that the largest gaps between the hole and each of the first wiring and the second wiring are not more than 5 mm. Consequently, it is possible to provide the plasma CVD apparatus capable of suppressing the generation of discharge at the back face of the anode.

Furthermore, in one aspect of the present invention, it is preferable to have a gap between the chamber and the anode, linked to the gap between the other end of the plasma wall and the anode, and that the largest part of the gap between the chamber and the anode is not more than 5 mm. Consequently, the generation of discharge at the back face of the anode can be suppressed more effectively.

Moreover, in one aspect of the present invention, it is preferable to have a gap between the chamber and the plasma wall, linked to the gap between the other end of the plasma wall and the anode, and that the largest part of the gap
5 between the chamber and the plasma wall is not more than 5 mm. Consequently, the generation of discharge at the back face of the anode can be suppressed more effectively.

An aspect of the present invention is a method for manufacturing a magnetic recording medium using the
10 above-mentioned plasma CVD apparatus, including the steps of: holding a substrate to be deposited in which at least a magnetic layer is formed on a nonmagnetic substrate in the holding part; and putting the raw material gas into a plasma state by discharge between the filament-shaped cathode
15 heated under vacuum conditions and the anode in the chamber, and accelerating and bombarding the plasma on the surface of the substrate to be deposited held by the holding part to form a protective layer having carbon as a main component.

In addition, in the method for manufacturing a magnetic
20 recording medium according to the present invention, preferably the raw material gas is a raw material gas for forming a DLC layer as the protective layer on the substrate to be deposited and includes a gas containing carbon and hydrogen.

25 An aspect of the present invention is a magnetic recording medium manufactured using the above-mentioned method for manufacturing a magnetic recording medium,

including:

the substrate to be deposited; and

the DLC layer formed on the substrate to be deposited.

EFFECT OF THE INVENTION

5 By applying one aspect of the present invention, it is possible to provide a plasma CVD apparatus capable of suppressing the generation of discharge at the back face of an anode, or a magnetic recording medium using the plasma CVD apparatus, or a method for manufacturing the same.

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BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1(A) is a cross-sectional view showing schematically the plasma CVD apparatus according to an embodiment, and Fig. 1(B) is a drawing showing a cathode and an AC power supply viewed from the direction of an arrow 16 shown in Fig. 1(A).

Fig. 2(A) is a photograph showing that adherence of a carbon film is absent in a gap between an anode 4 and a gas introduction flange 15 after an 8-hour continuous discharge test for the plasma CVD apparatus shown in Figs. 1(A) and 1(B), Fig. 2(B) is a photograph showing that adherence of a carbon film is absent in a gap between an anode cone 4a and each of first and second wirings 17a and 17b, 25 Fig. 2(C) is a photograph showing that adherence of a carbon film is present in the gap between an anode 104 and a gas introduction flange 115 after an 8-hour continuous discharge

test for the plasma CVD apparatus shown in Figs. 4(A) and 4(B), and Fig. 2(D) is a photograph showing that adherence of a carbon film is present in a gap between the anode 104 and a cathode back board 111.

5 Fig. 3 is a drawing showing a relational curve between the contact angle of water and Knoop hardness.

 Fig. 4(A) is a cross-sectional view showing schematically a conventional plasma CVD apparatus, and Fig. 4(B) is a drawing showing a cathode and an AC power supply
10 viewed from the direction of an arrow 116 shown in Fig. 4(A).

BEST MODE FOR CARRYING OUT THE INVENTION

 Hereinafter, embodiments of the present invention will be described in detail using the drawings. However, a person
15 skilled in the art can easily understand that the present invention is not limited to the description below, but that the form and detail thereof can be modified variously without departing from the purport and scope of the present invention. Accordingly, the present invention should not be construed
20 as being limited to the description of the embodiments shown below.

 Fig. 1(A) is a cross-sectional view showing schematically the plasma CVD apparatus according to an embodiment of the present invention, and Fig. 1(B) is a
25 drawing showing a cathode and an AC power supply viewed from the direction of an arrow 16 shown in Fig. 1(A).

 The plasma CVD apparatus is an apparatus that has a

left-right symmetrical structure with respect to a substrate to be deposited (for example, a disc substrate) 1 and is capable of deposition on both sides of the substrate to be deposited 1 simultaneously, but, in Fig. 1(A), the left side
5 relative to the substrate to be deposited 1 is shown and the right side is omitted.

The plasma CVD apparatus has a chamber 2, and to the chamber 2, a gas introduction flange 15 is mounted. The gas introduction flange 15 is connected to the earth. A
10 film-forming chamber is formed by the gas introduction flange 15 and the chamber 2, and thus the chamber may be referred to by including the gas introduction flange 15 and the chamber 2.

In the chamber, a plasma wall 8 is disposed. The plasma
15 wall 8 is mounted to the gas introduction flange 15, and the plasma wall 8 is electrically connected to float potential (not shown). The plasma wall 8 is disposed in a state of being insulated with respect to the chamber 2, and is also insulated with respect to the gas introduction flange 15. In addition,
20 the plasma wall 8 has a cylindrical shape or a polygonal cross-section, with opened both ends.

At one end of the plasma wall 8, a film thickness-correcting plate 8a is provided, and the film thickness-correcting plate 8a is electrically connected to
25 float potential. By the film thickness-correcting plate 8a, it is possible to control the thickness of a film to be deposited on the outer periphery of the substrate to be

deposited 1.

Near the opening of one end of the plasma wall 8, the substrate to be deposited 1 is provided, and it is configured such that the substrate to be deposited 1 is supplied sequentially to the position shown in the drawing by a holder (a holding part) not shown and a transfer device (a handling robot or a rotary index table) not shown.

The substrate to be deposited 1 is electrically connected to a DC power supply (a direct-current power supply) 12 as a power supply for ion acceleration, and the DC power supply 12 is disposed in a state of being insulated with respect to the chamber 2. The negative potential side of the DC power supply 12 is electrically connected to the substrate to be deposited 1, and the positive potential side of the DC power supply 12 is electrically connected to the earth 6. As the DC power supply 12, a power supply of, for example, 0 to 1500 V and 0 to 100 mA (milliampere) can be used.

In the gas introduction flange 15, an anode 4 including an anode cone 4a and an anode base 4b is disposed. Meanwhile, the cathode back board 111 as shown in Figs. 4(A) and 4(B) is not disposed, and the anode cone 4a shown in Figs. 1(A) and 1(B) is formed into a shape of integrating the anode cone 104a and cathode back board 111 shown in Figs. 4(A) and 4(B), to thereby be in a state where the gap between the anode cone 104a and the cathode back board 111 shown in Figs. 4(A) and 4(B) has been filled. Consequently, it is possible to

suppress the generation of discharge at the back face of the anode cone 4a and the adherence of a CVD film.

In other words, the anode cone 4a is disposed so as to cover the opening of the other end of the plasma wall 8. Furthermore, the anode cone 4a is set to have a speaker-like shape, and the anode cone 4a is disposed so that the largest inside diameter side thereof faces the substrate to be deposited 1.

Between the anode cone 4a and the other end of the plasma wall 8, a gap 18a is provided, and the largest part of the gap 18a is preferably not more than 5 mm, more preferably not more than 3 mm. Meanwhile, in the present embodiment, the clearance of the largest part of the gap 18a is set to be 3 mm. As described above, by setting the largest gap between the anode cone 4a and the other end of the plasma wall 8 to be not more than 5 mm, it is possible not to prevent the plasma from being kept in the space surrounded by the anode cone 4a and the plasma wall 8. That is, when setting the largest gap to be larger than 5 mm, there may be a risk that the plasma disperses toward the back face of the anode cone 4a or the outside (that is, the outside of the space surrounded by the anode cone 4a and the plasma wall 8) from the gap larger than 5 mm or the plasma generates abnormal discharge at the back face or the outside. In other words, by setting the largest gap to be not more than 5 mm, it is possible to suppress the deposition of a CVD film on the back face or outside of the anode cone 4a.

Furthermore, to the gap 18a, gaps 18b and 18c between the gas introduction flange 15 and each of the anode 4 and plasma wall 8 are linked, and the largest part of the gaps 18b and 18c is preferably not more than 5 mm.

5 Meanwhile, the whole of the gap 18b between the gas introduction flange 15 and the anode 4 may be not more than 5 mm at the most, or a part of the gap 18b between the gas introduction flange 15 and the anode 4 may be not more than 5 mm at the most and also the part of the gap 18b may be in
10 a state of being linked to the gap 18a. In addition, the whole of the gap 18c between the gas introduction flange 15 and the plasma wall 8 may be not more than 5 mm at the most, or a part of the gap 18c between the gas introduction flange 15 and the plasma wall 8 may be not more than 5 mm at the
15 most and also the part of the gap 18c may be in a state of being linked to the gap 18a. As described above, by setting at least a part of each of the gaps 18b and 18c linked to the gap 18a to be not more than 5 mm at the most, it is possible to suppress more effectively the generation of abnormal
20 discharge at the back face of the anode 4, and it is possible to suppress more effectively the deposition of a CVD film on the back face of the anode 4.

At the outside of the anode cone 4a (the side opposite to the inside of the plasma wall 8), an anode base 4b is
25 provided, and the anode base 4b is connected with the anode cone 4a. The anode base 4b is electrically connected to a DC power supply (a direct-current power supply) 7, and the

DC power supply 7, the anode base 4b and the anode cone 4a are disposed in a state of being insulated with respect to the gas introduction flange 15. The positive potential side of the DC power supply 7 is electrically connected to the anode base 4b and the anode cone 4a, and the negative potential side of the DC power supply 7 is electrically connected to an earth 6. As the DC power supply 7, a power supply of, for example, 0 to 500 V and 0 to 7.5 A (ampere) can be used.

In the gas introduction flange 15, a filament-shaped cathode (a hot cathode) 3 consisting of, for example, tantalum is formed, and the hot cathode 3 is disposed so as to face the substrate to be deposited 1. The hot cathode 3 is disposed inside the anode cone 4a and near the opening of the other end of the plasma wall 8, and is disposed so as to be surrounded by the anode cone 4a.

Both ends of the hot cathode 3 are electrically connected to an AC power supply 5 positioned outside the gas introduction flange 15. That is, one end of the hot cathode 3 is electrically connected to the AC power supply 5 via a first wiring 17a, and the other end of the hot cathode 3 is electrically connected to the AC power supply 5 via a second wiring 17b. The AC power supply 5 is disposed in a state of being insulated with respect to the gas introduction flange 15. As the AC power supply 5, a power supply of, for example, 0 to 50 V and 10 to 50 A (ampere) can be used. One end of the AC power supply 5 is electrically connected to the earth 6. Meanwhile, in the present embodiment, the AC power supply

5 is used, but in place of the AC power supply 5, a DC power supply may be used.

Each of the first wiring 17a and the second wiring 17b extends from the inside of the anode cone 4a to the outside through a hole 4c provided at the anode cone 4a. The hole 4c may have one hole or two holes. That is, it may be configured such that both the first wiring 17a and second wiring 17b go through one hole, or that the first wiring 17a goes through one hole and the second wiring 17b goes through the other hole.

The largest gap between the hole 4c and each of the first wiring 17a and the second wiring 17b is preferably not more than 5 mm, more preferably not more than 3 mm. As described above, by setting the largest gap to be not more than 5 mm, it is possible not to prevent the plasma from being kept in the space surrounded by the anode cone 4a and the plasma wall 8. That is, when setting the largest gap to be larger than 5 mm, there may be a risk that the plasma disperses toward the back face or the outside of the anode cone 4a from the gap larger than 5 mm, to thereby generate abnormal discharge at the back face or the outside. In other words, by setting the largest gap to be not more than 5 mm, it is possible to suppress the deposition of a CVD film on the back face or outside of the anode cone 4a.

Furthermore, to the gaps between the hole 4c and each of the first wiring 17a and second wiring 17b, the gap between the gas introduction flange 15 and the anode 4 is linked,

and the largest part of the gap may be not more than 5 mm. However, it is not indispensable that the largest part of the gap is not more than 5 mm.

Meanwhile, the whole of the gap between the
5 above-mentioned gas introduction flange 15 and the anode 4 may be not more than 5 mm at the most, or a part of the gap between the gas introduction flange 15 and the anode 4 may be not more than 5 mm at the most and also the part of the gap may be in a state of being linked to the gap between the
10 hole 4c and each of the first wiring 17a and the second wiring 17b. By adopting such a state, it is possible to suppress more effectively the generation of abnormal discharge at the back face of the anode 4, and to suppress more effectively the deposition of a CVD film on the back face of the anode
15 4.

Outside the gas introduction flange 15, a neodymium magnet 9 is disposed. The neodymium magnet 9 has, for example, a cylindrical shape or a polygonal cross-section, and the distance between the inside diameter passing through the
20 center of the cylinder side face or the polygonal side face in the tube direction, and the hot cathode 3, is preferably within 50 mm (more preferably within 35 mm). The center of the inside diameter acts as the magnet center, and the magnet center is positioned so as to face each of the approximate
25 center of the hot cathode 3 and the approximate center of the substrate to be deposited 1. The neodymium magnet 9 has preferably a magnetic force, at the magnet center, of not

less than 50 G and not more than 200 G (gauss), more preferably of not less than 50 G and not more than 150 G. The reason why the magnetic force at the magnet center is set to be not more than 200 G is that, in neodymium magnets, the heightening
5 of the magnetic force at the magnet center up to 200 G is the manufacturing limitation. In addition, the reason why the magnetic force at the magnet center is more preferably set to be not more than 150 G is that, when the magnetic force at the magnet center exceeds 150 G, cost of fabricating a
10 magnet increases.

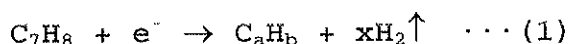
In addition, the plasma CVD apparatus has an evacuation mechanism (not shown) that evacuates the inside of the chamber. Furthermore, the plasma CVD apparatus has a gas supply mechanism (not shown) supplying a deposition raw
15 material gas into the chamber, and a gas introduction part 15a of the gas supply mechanism is provided at the gas introduction flange 15.

Next, there will be described a method for depositing a DLC film on the substrate to be deposited 1 using the plasma
20 CVD apparatus shown in Figs. 1(A) and 1(B).

First, the evacuation mechanism is started, the inside of the chamber is put into a predetermined vacuum state, and for example, toluene (C_7H_8) gas is introduced into the chamber as a deposition raw material gas by the gas introduction
25 mechanism. After the inside of the chamber reached a predetermined pressure, by supplying an alternating current to the hot cathode 3 by the AC power supply 5, the hot cathode

3 is heated. In addition, to the anode 4, a direct current is supplied by the DC power supply 7, and, to the substrate to be deposited 1, a direct current is supplied by the DC power supply 12.

5 By heating the hot cathode 3, a large quantity of electrons are emitted from the hot cathode 3 toward the anode cone 4a, and glow discharge is started between the hot cathode 3 and the anode cone 4a. By the large quantity of electrons, toluene gas as a deposition raw material gas inside the
10 chamber is ionized to be put into a plasma state. At this time, a magnetic field is generated in a region for converting the toluene gas positioned near the hot cathode 3 into plasma by the neodymium magnet 9, and thus it is possible to densify the plasma by the magnetic field and to improve ionization
15 efficiency. Then, deposition raw material molecules in a plasma state are directly accelerated by negative potential of the substrate to be deposited 1, fly toward the direction of the substrate to be deposited 1, and adhere onto the surface of the substrate to be deposited 1. Consequently, a thin DLC
20 film is formed on the substrate to be deposited 1. At this time, on the surface of the substrate to be deposited 1, a reaction of the following Formula (1) is being caused.



Next, there will be described a method for
25 manufacturing a magnetic recording medium using the plasma CVD apparatus shown in Figs. 1(A) and 1(B).

First, a substrate to be deposited in which at least

a magnetic layer is formed on a nonmagnetic substrate is prepared, and the substrate to be deposited is held by a holding part. Next, by discharge between the hot cathode 3 heated under a predetermined vacuum condition and the anode cone 4a in the chamber, a raw material gas is put into a plasma state, and the plasma is accelerated and bombarded on the surface of the substrate to be deposited held by the holding part. Consequently, on the surface of the substrate to be deposited, a protective layer in which carbon is a main component is formed. Meanwhile, when forming a DLC layer as a protective layer, a gas containing carbon and hydrogen can be used as a raw material gas.

Next, the effect obtained by the present embodiment will be described.

In the conventional plasma CVD apparatus shown in Figs. 4(A) and 4(B), since there exists the gap 113 between the cathode back board 111 and the anode cone 104a, discharge may be generated at the back face of the anode cone 104a, to thereby lead to the adherence of the carbon film 110a.

In contrast to this, in the plasma CVD apparatus of the present embodiment shown in Figs. 1(A) and 1(B), the anode cone 4a shown in Figs. 1(A) and 1(B) is made into a shape in which the anode cone 104a and the cathode back board 111 shown in Figs. 4(A) and 4(B) are integrated, and the largest gap between the hole 4c of the anode cone 4a and each of the first wiring 17a and the second wiring 17b is set to be not more than 5 mm, and the largest gap between the anode cone

4a and the other end of the plasma wall 8 is set to be not more than 5 mm, and accordingly, it is possible to suppress the generation of discharge at the back face of the anode cone 4a and the adherence of a CVD film. In addition, it is possible to suppress, by the peeling of the CVD film having adhered as is the case with conventional techniques, the adherence of the peeled CVD film to the substrate to be deposited and the generation of failures in the magnetic recording medium.

10 By suppressing the generation of discharge at the back face of the anode cone 4a, since the loss of power consumption as in the case of conventional techniques does not exist, the lowering of energy to be used for the decomposition of a raw material gas by the power loss also does not exist, 15 and there also exists no risk of the lowering of film quality of the film deposited on the substrate to be deposited 1.

Examples

[Example 1]

For the plasma CVD apparatus shown in Figs. 1(A) and 20 1(B), an 8-hour continuous discharge test was carried out.

(Common test conditions)

Substrate to be deposited: Si wafer

Raw material gas: C_7H_8

Gas flow rate: 3.25 sccm

25 Pressure: 0.3 Pa

Anode voltage V_p (voltage of DC power supply 7): 75

V

Plasma current I_p (current of DC power supply 7): 1650
mA

Substrate bias (voltage of DC power supply 12): -250
V

5 Hot cathode 3: tantalum filament

Output of AC power supply 5: 200 W

External magnetic field: 50 gauss

(Results)

For the gaps between the anode cone 4a and each of the
10 first and second wirings 17a and 17b, there was no adherence
of a carbon film (see Fig. 2(B)).

For the gap between the anode 4 and the gas introduction
flange 15, there were no adherence of a carbon film, and in
addition, no trace of abnormal discharge (see Fig. 2(A)).

15 [Comparative Example 1]

For the plasma CVD apparatus shown in Figs. 4(A) and
4(B), an 8-hour continuous discharge test was carried out.

(Common test conditions)

Substrate to be deposited: Si wafer

20 Raw material gas: C_7H_8

Gas flow rate: 3.25 sccm

Pressure: 0.3 Pa

Anode voltage V_p (voltage of DC power supply 7): 75
V

25 Plasma current I_p (current of DC power supply 7): 1650
mA

Substrate bias (voltage of DC power supply 12): -250

V

Hot cathode 3: tantalum filament

Output of AC power supply 5: 200 W

External magnetic field: 50 gauss

5 (Results)

There was the adherence of a carbon film in the gap between the anode 104 and the cathode back board 111 (Figs. 2(C) and 2(D)).

There were the adherence of a carbon film in the gap
10 between the anode 104 and the gas introduction flange 115, and in addition, the trace of abnormal discharge in several places (Fig. 2(C)).

[Example 2]

Using the plasma CVD apparatus shown in Figs. 1(A) and
15 1(B), a DLC film having a thickness of 40 nm was deposited on a 3.5-inch medium under the following common test conditions, and the hardness of the DLC film was evaluated by measuring the contact angle of water with respect to the deposited DLC film. The relationship between the contact
20 angle and the hardness is as shown in Fig. 3.

(Common test conditions)

Substrate to be deposited: 3.5-inch medium

Raw material gas: C_7H_8

Gas flow rate: 3.25 sccm

25 Pressure: 0.3 Pa

Anode voltage V_p (voltage of DC power supply 7): 75

V

Plasma current I_p (current of DC power supply 7): 1650
mA

Substrate bias (voltage of DC power supply 12): -250
V, -300 V, and -350 V

5 Hot cathode 3: tantalum filament

Output of AC power supply 5: 200 W

External magnetic field: 50 gauss

(Results)

Substrate bias -250 V: Knoop hardness 2930 HK (contact
10 angle 57°)

Substrate bias -300 V: Knoop hardness 2970 HK (contact
angle 56°)

Substrate bias -350 V: Knoop hardness 3000 HK (contact
angle 55°)

15 [Comparative Example 2]

Using the plasma CVD apparatus shown in Figs. 4(A) and
4(B), a DLC film having a thickness of 40 nm was deposited
on a 3.5-inch medium under the following common test
conditions, and the hardness of the DLC film was evaluated
20 by measuring the contact angle of water with respect to the
deposited DLC film. The relationship between the contact
angle and the hardness is as shown in Figs. 2(A) to 2(D).

(Common test conditions)

Substrate to be deposited: 3.5-inch medium

25 Raw material gas: C_7H_8

Gas flow rate: 3.25 sccm

Pressure: 0.3 Pa

Anode voltage V_p (voltage of DC power supply 7): 75
V

Plasma current I_p (current of DC power supply 7): 1650
mA

5 Substrate bias (voltage of DC power supply 12): -250
V, -300 V, and -350 V

Hot cathode 3: tantalum filament

Output of AC power supply 5: 200 W

External magnetic field: 50 gauss

10 (Results)

Substrate bias -250 V: Knoop hardness 2650 HK (contact
angle 65°)

Substrate bias -300 V: Knoop hardness 2770 HK (contact
angle 62°)

15 Substrate bias -350 V: Knoop hardness 2830 HK (contact
angle 60°)

According to each of results in Example 2 and
Comparative Example 2, since the contact angle in Example
2 is smaller than that in Comparative Example 2, it was
20 confirmed that a DLC film having higher hardness was
deposited in Example 2 as compared with Comparative Example
2.

DESCRIPTION OF SYMBOLS

- 25 1, 101: substrate to be deposited
2, 102: chamber
3, 103: cathode (hot cathode)
4, 104: anode

4a, 104a: anode cone
4b, 104b: anode base
4c: hole
5, 105: AC power supply
5 6, 106: earth
7, 107: DC power supply
8, 108: plasma wall
8a: film thickness-correcting plate
9: neodymium magnet
10 12, 112: DC power supply
15, 115: gas introduction flanges
15a, 115a: gas introduction part
17a: first wiring
17b: second wiring
15 109: magnet
110a: carbon film
110b: particles of carbon film
111: cathode back board
113: gap
20 114: ring-shaped space
116: arrow

CLAIMS

1. A plasma CVD apparatus, comprising:
 - a chamber;
 - a plasma wall that is disposed in said chamber and has
 - 5 a cylindrical shape or a polygonal cross-section with opened both ends;
 - a holding part that is disposed in said chamber and holds a substrate to be deposited disposed near the opening of one end of said plasma wall;
 - 10 an anode that is disposed in said chamber and is disposed so as to cover the opening of the other end of said plasma wall;
 - a filament-shaped cathode that is disposed in said chamber, is disposed on an inner side of said anode and near
 - 15 the opening of the other end of said plasma wall, and is disposed facing said substrate to be deposited held by said holding part;
 - an AC power supply or a DC power supply which is disposed outside said chamber, is electrically connected to one end
 - 20 of said cathode via a first wiring, and is electrically connected to the other end of said cathode via a second wiring;
 - a hole which is provided at said anode, and through which each of said first wiring and said second wiring passes;
 - a first DC power supply that is disposed outside said
 - 25 chamber and is electrically connected to said anode;
 - a second DC power supply that is disposed outside said chamber and is electrically connected to said substrate to

be deposited held by said holding part;

a gas supply mechanism supplying a raw material gas into said chamber; and

an exhaust mechanism exhausting the inside of said chamber.

2. The plasma CVD apparatus according to claim 1, wherein:
the largest gap between the other end of said plasma wall and said anode is not more than 5 mm; and

10 the largest gaps between said hole and each of said first wiring and said second wiring is not more than 5 mm.

3. The plasma CVD apparatus according to claim 2, having a gap between said chamber and said anode, linked to the gap
15 between the other end of said plasma wall and said anode, the largest part of said gap between said chamber and said anode being not more than 5 mm.

4. The plasma CVD apparatus according to claim 2 or 3,
20 having a gap between said chamber and said plasma wall, linked to the gap between the other end of said plasma wall and said anode, the largest part of said gap between said chamber and said plasma wall being not more than 5 mm.

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

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

5 putting said raw material gas into a plasma state by discharge between said filament-shaped cathode heated under vacuum conditions and said anode in said chamber, and accelerating and bombarding the plasma on the surface of the substrate to be deposited held by said holding part to form a protective layer having carbon as a main component.

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6. The method for manufacturing a magnetic recording medium according to claim 5, wherein said raw material gas is a raw material gas for forming a DLC layer as said protective layer on said substrate to be deposited and
15 includes a gas containing carbon and hydrogen.

7. A magnetic recording medium manufactured using the method for manufacturing a magnetic recording medium according to claim 6, comprising:

20 said substrate to be deposited; and
said DLC layer formed on said substrate to be deposited.