

PLASMA CVD APPARATUS AND METHOD FOR MANUFACTURING MAGNETIC RECORDING MEDIUM

BACKGROUND OF THE INVENTION

5 Field of the Invention

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

Description of a Related Art

10 Fig. 5 is a cross-sectional view showing schematically a plasma CVD apparatus. The plasma CVD apparatus is an apparatus for depositing a thin film on both surfaces of a substrate to be deposited 101, and is bilaterally symmetrically configured with respect to the substrate to
15 be deposited 101, and in Fig. 5, only the left side is shown.

The plasma CVD apparatus has a chamber, and in the chamber 102, a filament-shaped cathode electrode 103 including, for example, tantalum, is formed. Both ends of the cathode electrode 103 are electrically connected to a
20 cathode power source 105, and the cathode power source 105 is electrically connected to an earth 106. So as to surround the circumference of the cathode electrode 103, an anode electrode 104 having a funnel-like shape is disposed. The anode electrode 104 is electrically connected to the positive
25 potential side of a DC (direct current) power source 107, and the negative potential side of the DC power source 107 is electrically connected to the earth.

In the chamber 102, the substrate to be deposited 101 is disposed, and the substrate to be deposited 101 is disposed so as to face the cathode electrode 103 and the anode electrode 104. The substrate to be deposited 101 is electrically
5 connected to the negative potential side of a bias power source (a DC power source) 112 as a power source for ion acceleration, and the positive potential side of the DC power source 112 is electrically connected to the earth 106.

In the chamber 102, an inner shield 108 is disposed
10 so as to cover spaces between each of the cathode electrode 103 and the anode electrode 104 and the substrate to be deposited 101.

Furthermore, the plasma CVD apparatus has a vacuum exhaust mechanism (not shown) for evacuating the inside of
15 the chamber 102. The plasma CVD apparatus has a gas-supplying mechanism (not shown) for supplying a deposition raw material gas into the chamber (for example, see Japanese Patent No. 3930181 (Fig. 1)).

There is a desire to control, with good uniformity,
20 the thickness of a film to be deposited on the substrate to be deposited 101 by the plasma processing apparatus.

SUMMARY OF THE INVENTION

An aspect of the present invention aims at providing
25 a plasma CVD apparatus or a method for manufacturing a magnetic recording medium, which can control, with good uniformity, the thickness of a film to be deposited on a

substrate to be deposited.

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

(1) A plasma CVD apparatus, including:

5 a chamber;

an anode disposed in the chamber;

a cathode disposed in the chamber;

a holding part that is disposed in the chamber and holds
a substrate to be deposited disposed so as to face the cathode
10 and the anode;

an inner shield that is disposed in the chamber and
is provided so as to cover spaces between the substrate to
be deposited held by the holding part and each of the anode
and the cathode;

15 a magnet disposed in the chamber, disposed outside the
inner shield and disposed so as to surround the inner shield;

a first direct current power source electrically
connected to the anode;

an alternating current power source electrically
20 connected to the cathode;

a second direct current power source electrically
connected to the substrate to be deposited held by the holding
part;

a gas-supplying mechanism for supplying a raw material
25 gas into the chamber; and

an exhaust mechanism for exhausting an inside of the
chamber;

wherein distance between a plane that is parallel to a surface of the substrate to be deposited and includes an end part of the magnet on a side of the substrate to be deposited and a surface of the substrate to be deposited is
5 from 15 mm to 100 mm (preferably from 20 mm to 50 mm).

(2) The plasma CVD apparatus according to the above (1), wherein:

the inner shield is surrounded by $2n$ magnets; and
in each of the $2n$ magnets, either an N pole or an S
10 pole faces an inside of the inner shield and, in the magnets adjacent to each other, magnetic poles facing the inside of the inner shield are opposite to each other,
where n is an integer of 2 to 12.

(3) The plasma CVD apparatus according to the above
15 (2), wherein a magnetic field in an outer periphery of the substrate to be deposited is from ± 0.1 G to ± 50 G (preferably from ± 1 G to ± 40 G).

(4) The plasma CVD apparatus according to the above (1), wherein;

20 the inner shield is surrounded by one magnet; and
in the one magnet, either an N pole or an S pole faces a side of the cathode and the other of the N pole or the S pole faces a side of the substrate to be deposited.

(5) The plasma CVD apparatus according to any one of
25 above (1) to (4), wherein:

the apparatus has an outer shield that is disposed in the chamber and is disposed outside the inner shield; and

the magnet is positioned outside the outer shield.

(6) A method for manufacturing a magnetic recording medium using the plasma CVD apparatus according to any one of above (1) to (5), wherein:

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

 in the chamber, the raw material gas is put into a plasma state by discharge between the cathode and the anode, and
10 the plasma is accelerated and bombarded on a surface of the substrate to be deposited held by the holding part to form a protective layer having carbon as a main component.

(7) A method for manufacturing a magnetic recording medium in which at least a magnetic layer is formed on a
15 nonmagnetic substrate, and after that, a protective layer having carbon as a main component is formed, wherein the plasma CVD apparatus according to any one of above (1) to (5) is used to form the protective layer.

 According to an embodiment of the present invention,
20 it is possible to provide a plasma CVD apparatus or a method for manufacturing a magnetic recording medium, which can control, with good uniformity, the thickness of a film to be deposited on a substrate to be deposited.

25 BRIEF DESCRIPTION OF THE DRAWINGS

 Fig. 1 is a cross-sectional view showing schematically a plasma CVD apparatus according to an embodiment 1.

Fig. 2 is a cross-sectional view showing schematically a plasma CVD apparatus according to an embodiment 2.

Fig. 3A is a photograph of a DLC film 10 deposited on a substrate to be deposited 1 by using a plasma processing apparatus shown in Fig. 2, and Fig. 3B is a cross-sectional view showing schematically the thickness of the DLC film 10 deposited on the substrate to be deposited 1 shown in Fig. 3A.

Fig. 4A is a photograph of a DLC film 11 deposited on the substrate to be deposited 1 by using an apparatus obtained by removing a magnet 119 from the plasma CVD apparatus shown in Fig. 2, and Fig. 4B is a cross-sectional view showing schematically the thickness of the DLC film 11 deposited on the substrate to be deposited 1, shown in Fig. 4A.

Fig. 5 is a cross-sectional view showing schematically a plasma CVD apparatus.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, embodiments of the present invention will be explained in detail using the drawings. However, the present invention is not limited to the description below and it is easily understood by those skilled in the art that the modes and details can be variously modified without departing from the gist and scope of the invention. Therefore, the present invention should not be construed as being limited to the description of the following embodiments.

[Embodiment 1]

<Plasma CVD apparatus>

Fig. 1 is a cross-sectional view showing schematically a plasma CVD apparatus according to an embodiment of the present invention. The plasma CVD apparatus has a bilaterally symmetrical construction with respect to a substrate to be deposited (for example, a disc substrate) 1, and is an apparatus capable of depositing simultaneously films on both faces of the substrate to be deposited 1, but in Fig. 1, only the left side is shown.

The plasma CVD apparatus has a chamber 102, and in the chamber 102, a cathode electrode (a cathode filament) 103 in a filament shape, including, for example, tantalum is formed. Both ends of the cathode filament 103 are electrically connected to a cathode power source (an alternating current power source) 105 positioned outside the chamber 102, and the cathode power source 105 is disposed in an insulated state for the chamber 102.

The cathode power source 105 is controlled by a control part not shown. Consequently, a voltage applied to the cathode filament 103 is controlled. Meanwhile, as the cathode power source 105, for example, a power source of 0 to 50 V and of 10 to 50 A (ampere) can be employed. One end of the cathode power source 105 is electrically connected to the earth 106.

In the chamber 102, an anode electrode (an anode cone) 104 having a funnel-like shape is disposed so as to surround

respective peripheries of the cathode filament 103, and the anode cone 104 is made into be a speaker-like shape.

The anode cone 104 is electrically connected to an anode power source (a DC (direct current) power source) 107, and
5 the DC power source 107 is disposed in an insulated state for the chamber 102. The positive potential side of the DC power source 107 is electrically connected to the anode cone 104, and the negative potential side of the DC power source 107 is electrically connected to the earth 106.

10 The DC power source 107 is controlled by the control part. Consequently, a voltage applied to the anode cone 104 is controlled. Meanwhile, as the DC power source 107, for example, a power source of 0 to 500 V and of 0 to 7.5 A (ampere) can be employed.

15 In the chamber 102, the substrate to be deposited 1 is disposed, and the substrate to be deposited 1 is disposed so as to face the cathode filament 103 and the anode cone 104. In detail, the cathode filament 103 is encircled near the central part of the inner peripheral surface of the anode
20 cone 104, and the anode cone 104 is disposed with the maximum inside diameter side being toward the substrate to be deposited 1.

It is configured such that the substrate to be deposited 1 is supplied sequentially to a shown position by a holder
25 (holding part) not shown and a transfer apparatus (a handling robot or a rotary index table) not shown.

The substrate to be deposited 1 is electrically

connected to a bias power source (a DC power source ,direct
current power source) 112 as a power source for ion
acceleration, and the DC power source 112 is disposed in an
insulated state for the chamber 102. The negative
5 potential side of the DC power source 112 is electrically
connected to the substrate to be deposited 1, and the positive
potential side of the DC power source 112 is electrically
connected to the earth 106.

The DC power source 112 is controlled by the control
10 part. Consequently, a voltage applied to the substrate to
be deposited 1 is controlled. Meanwhile, as the DC power
source 112, for example, a power source of 0 to 1500 V and
0 to 100 mA (milliamperes) can be employed.

On a side the substrate to be deposited 1 of the anode
15 cone 104, an inner shield 108 including a conductor is
provided, and the inner shield 108 is formed so as to cover
spaces between each of the cathode filament 103 and anode
cone 104 and the substrate to be deposited 1. The inner
shield 108 is set at a floating potential, and is disposed
20 in an insulating state against the chamber 102. In addition,
the inner shield 108 has a cylindrical or a polygonal shape.

At the end part of the inner shield 108 on a side of
the substrate to be deposited 1, a film thickness-correcting
plate 118 is provided. The film thickness-correcting plate
25 118 is electrically connected to the inner shield 108, and
is set at a floating potential. The film
thickness-correcting plate 118 controls the thickness of a

film to be deposited in an outer periphery part of the substrate to be deposited 1.

In the outside of the inner shield 108, an outer shield 90 including an electric conductor or an insulator is disposed so as to cover the inner shield 108, and the outer shield 90 has a cylindrical or a polygonal shape. In addition, the outer shield 90 is electrically connected to a floating potential or the earth potential. The outer shield 90 has a function to prevent discharge between the chamber 102 and the inner shield 108.

In a position inside the chamber 102 and outside the outer shield 90, one magnet (for example, a neodymium magnet) 109 is disposed, the magnet 109 being disposed so as to surround the inner shield 108. The magnet 109 is disposed on a side closer to the substrate to be deposited 1 than the cathode filament 103. In detail, it is favorable that the distance between a plane 109c, which is parallel to the surface of the substrate to be deposited 1 (the surface on a side of the magnet 109) and which includes an end part 109b of the magnet 109 on a side of the substrate to be deposited 1, and the surface of the substrate to be deposited 1 is from 15 mm to 100 mm (preferably from 20 mm to 50 mm).

The magnet 109 has, for example, a cylindrical shape or a polygonal shape, the center of the inside diameter of the cylindrical or a polygonal shape serves as a magnet center, and the magnet center is positioned so as to face each of an approximate center of the cathode filament 103 and an

approximate center of the substrate to be deposited 1. The magnet center is positioned at a position closer to the approximate center of the substrate to be deposited 1 than the approximate center of the cathode filament 103.

5 In the magnet 109, the N pole faces a side of the cathode filament 103, and the S pole faces a side of the substrate to be deposited 1.

 In addition, the plasma CVD apparatus has a vacuum exhaust mechanism (not shown) for evacuating the inside of
10 the chamber 102. Furthermore, the plasma CVD apparatus has a gas-supplying mechanism (not shown) for supplying a deposition raw material gas into the chamber 102 from a gas introductory part 102a.

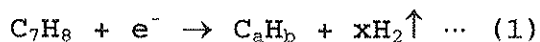
<Deposition method>

15 A method for depositing a DLC (Diamond Like Carbon) film on the substrate to be deposited 1 by using the plasma CVD apparatus shown in Fig. 1 will be explained.

 First, by the activation of the vacuum exhaust mechanism, the inside of the chamber 102 is put into a
20 prescribed vacuum state, and, from the gas introductory part 102a into the inside of the chamber 102, for example, toluene (C_7H_8) gas as the deposition raw material gas is introduced by the gas introductory mechanism. After the inside of the chamber 102 reaches a prescribed pressure, an alternating
25 current is supplied to the cathode filament 103 from the cathode power source 105, and thus the cathode filament 103 is heated.

In addition, to the substrate to be deposited 1, a direct current is supplied from the DC power source 112. In addition, to the anode cone 104, a direct current is supplied from the DC power source 107. Furthermore, a magnetic field
5 is formed near the surface of the substrate to be deposited 1 and in a position facing the surface, by the magnet 109.

By heating the cathode filament 103, a lot of electrons are emitted from the cathode filament 103 toward the anode cone 104 and glow discharge is started between the cathode
10 filament 103 and the anode cone 104. By the lot of electrons, the toluene gas as the deposition raw material gas inside the chamber 102 is ionized to be put into a plasma state 109a. In addition, deposition raw material molecules in the plasma state are directly accelerated by the negative potential of
15 the substrate to be deposited 1, fly and travel toward the direction of the substrate to be deposited 1, and adhere to the surface of the substrate to be deposited 1. At this time, it is possible to cause deposition raw material molecules toward the surface of the substrate to be deposited 1, to
20 fly and travel, with better uniformity, by the magnetic field due to the magnet 109. As the result, a DLC film having good thickness uniformity can be formed on the substrate to be deposited 1. In particular, the controllability of the thickness of a film to be deposited in an outer periphery
25 of the substrate to be deposited 1 can be enhanced. Meanwhile, on the surface of the substrate to be deposited 1, a reaction in the following formula (1) is generated.



Next, a method for manufacturing a magnetic recording medium using the plasma CVD apparatus shown in Fig. 1 will be explained.

5 First, there is prepared a substrate to be deposited in which at least a magnetic layer is formed on a nonmagnetic substrate, and the substrate to be deposited is held by the holding part. Next, by discharge between the cathode filament 103 heated under a prescribed vacuum condition in
10 the chamber 102 and the anode cone 104, the 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 in the holding part. Consequently, on the surface of the substrate to be deposited, the protective layer having
15 carbon as a main component is formed.

According to the method for manufacturing a magnetic recording medium, due to the magnetic field formed by the magnet 109, a DLC film having good thickness uniformity can be formed on the substrate to be deposited 1. In particular,
20 the controllability of thickness of a film to be deposited in an outer periphery part of the substrate to be deposited 1 can be enhanced.

[Embodiment 2]

<Plasma CVD apparatus>

25 Fig. 2 is a cross-sectional view showing schematically the plasma CVD apparatus according to an aspect of the present invention, in which the same symbol is attached to the same

part and explanation of the same part is omitted. The plasma CVD apparatus has a bilaterally symmetrical structure with respect to the substrate to be deposited (for example, a disc substrate) 1 and is an apparatus capable of depositing
5 simultaneously films on both surfaces of the substrate to be deposited 1, but, in Fig. 2, only the left side is shown.

Inside the chamber 102 and outside the outer shield 90, $2n$ magnets (for example, neodymium magnets) 119 are disposed, and the $2n$ magnets 119 are disposed so as to surround
10 the inner shield 108. However, n is preferably an integer of 2 to 12, or n may be an integer of 4 to 10.

As to each of the $2n$ magnets 119, either the N pole or the S pole faces the inside of the inner shield 108, the other of the N pole or the S pole faces the outside of the
15 inner shield 108, and, in the magnets 119 adjacent to each other, magnetic poles facing the inside of the inner shield 108 are opposite to each other. For example, when 4 magnets 119 are disposed, the magnetic field 119a is formed so as to face the surface of the substrate to be deposited 1 by
20 these magnets 119. In addition, when 8 magnets 129 are disposed, the magnetic field 129a is formed so as to face the surface of the substrate to be deposited 1 by these magnets 129.

It is favorable that the distance between a plane 119c,
25 which is parallel to the surface of the substrate to be deposited 1 (the surface on a side of the magnet 119) and which includes an end part 119b of the magnet 119 on a side

of the substrate to be deposited 1, and the surface of the substrate to be deposited 1 is from 15 mm to 100 mm (preferably from 20 mm to 50 mm).

The 2n magnets 119 are disposed so as to form a
5 cylindrical shape or a polygonal shape, the center of the inside diameter of the cylinder or polygon serves as a magnet center 119d, and the magnet center 119d is positioned so as to face each of an approximate center of the cathode filament 103 and an approximate center of the substrate to be deposited
10 1. The magnet center 119d is positioned closer to the approximate center of the substrate to be deposited 1 than the approximate center of the cathode filament 103.

The magnetic field formed in the outer periphery of the substrate to be deposited 1 by the magnets 119 and 129
15 is favorably from ± 0.1 G (gauss) to ± 50 G (preferably from ± 1 G to ± 40 G). This is the range obtained from the result of measuring the magnetic field while arranging, respectively, 4 magnets 119, 8 magnets 119, 16 magnets 119, or 24 magnets 119 for the plasma CVD apparatus. This range
20 makes it possible to enhance the controllability of the thickness of the film to be deposited in the outer periphery part of the substrate to be deposited 1.

Meanwhile, the outer periphery of the substrate to be deposited 1 corresponds, for example, to the circumference
25 of a circle having a radius of 32.5 mm from the magnet center 119d when the substrate to be deposited is a 2.5-inch substrate, and to the circumference of a circle having a

radius of 47.5 mm from the magnet center 119d when the substrate to be deposited is a 3.5-inch substrate.

<Deposition method>

5 A method for depositing a DLC film on the substrate to be deposited 1 by using the plasma CVD apparatus shown in Fig. 2 will be explained.

First, by the activation of the vacuum exhaust mechanism, the inside of the chamber 102 is put into a prescribed vacuum state, and, from the gas introductory part 10
10 102a into the inside of the chamber 102, for example, toluene (C_7H_8) gas as the deposition raw material gas is introduced by the gas introductory mechanism. After the inside of the chamber 102 reaches a prescribed pressure, an alternating current is supplied to the cathode filament 103 from the
15 cathode power source 105, and thus the cathode filament 103 is heated.

In addition, to the substrate to be deposited 1, a direct current is supplied from the DC power source 112. In addition, to the anode cone 104, a direct current is supplied
20 from the DC power source 107. Furthermore, a magnetic field is formed in a position which is near the surface of the substrate to be deposited 1 and which faces the surface, by the magnet 119.

By heating the cathode filament 103, a lot of electrons
25 are emitted from the cathode filament 103 toward the anode cone 104 and glow discharge is started between the cathode filament 103 and the anode cone 104. By the lot of electrons,

the toluene gas as the deposition raw material gas inside the chamber 102 is ionized to be put into a plasma state. In addition, deposition raw material molecules in the plasma state are directly accelerated by the negative potential of the substrate to be deposited 1, fly and travel toward the direction of the substrate to be deposited 1, and adhere to the surface of the substrate to be deposited 1. At this time, it is possible to cause deposition raw material molecules toward the surface of the substrate to be deposited 1, to fly and travel, with better uniformity, by the magnetic field due to the magnet 119. As the result, a DLC film having good thickness uniformity can be formed on the substrate to be deposited 1. In particular, the controllability of the thickness of a film to be deposited in an outer periphery of the substrate to be deposited 1 can be enhanced.

Next, a method for manufacturing a magnetic recording medium using the plasma CVD apparatus shown in Fig. 2 will be explained.

First, there is prepared a substrate to be deposited in which at least a magnetic layer is formed on a nonmagnetic substrate, and the substrate to be deposited is held by the holding part. Next, by discharge between the cathode filament 103 heated under a prescribed vacuum condition in the chamber 102 and the anode cone 104, the 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 in the holding part. Consequently, on the surface of

the substrate to be deposited, the protective layer having carbon as a main component is formed.

According to the method for manufacturing a magnetic recording medium, due to the magnetic field formed by the magnet 119, a DLC film having good thickness uniformity can be formed on the substrate to be deposited 1. In particular, the controllability of thickness of a film to be deposited in an outer periphery part of the substrate to be deposited 1 can be enhanced.

10 [Examples]

(Example 1)

Fig. 3A is a photograph of a DLC film 10 deposited on the substrate to be deposited 1 by using the plasma processing apparatus shown in Fig. 2, and Fig. 3B is a cross-sectional view showing schematically the thickness of the DLC film 10 deposited on the substrate to be deposited 1 shown in Fig. 3A.

The following describes conditions when the DLC film 10 shown in Figs. 3A and 3B was deposited.

20 Deposition apparatus: an apparatus obtained by disposing 16 magnets in the plasma CVD apparatus shown in Fig. 2

Substrate to be deposited 1: a glass disc with a metal layer

25 Starting material: high purity toluene

Gas flow rate: 3.0 sccm

Pressure: 0.3 Pa

Deposition time: 2 sec × 5 times

Cathode filament 103: a tantalum filament

Output power of alternating current power source 105:
230 W

5 Current of DC power source 107: 1650 mA

Voltage of DC power source 112: 250 V

(Comparative example 1)

Fig. 4A is a photograph of a DLC film 11 deposited on
the substrate to be deposited 1 by using an apparatus obtained
10 by removing the magnet 119 from the plasma CVD apparatus shown
in Fig. 2, and Fig. 4B is a cross-sectional view showing
schematically the thickness of the DLC film 11 deposited on
the substrate to be deposited 1 shown in Fig. 4A.

The following describes conditions when the DLC film
15 11 shown in Figs. 4A and 4B was deposited.

Deposition apparatus: an apparatus obtained by
removing the magnet 119 from the plasma CVD apparatus shown
in Fig. 2

Substrate to be deposited 1: a glass disc with a metal
20 layer

Starting material: high purity toluene

Gas flow rate: 3.0 sccm

Pressure: 0.3 Pa

Deposition time: 2 sec × 5 times

25 Cathode filament 103: a tantalum filament

Output power of alternating current power source 105:
230 W

Current of DC power source 107: 1650 mA

Voltage of DC power source 112: 250 V

In the Comparative example, as shown in Fig. 4B, the thickness of the DLC film 11 near the outer periphery of the substrate to be deposited 1 has become large, whereas in the Example 1, as shown in Fig. 3B, the thickness of the DLC film 10 near the outer periphery of the substrate to be deposited 1 has become smaller as compared with that in Comparative example. Accordingly, it is confirmed that the thickness of the film to be deposited on the substrate to be deposited 1 can be controlled, with good uniformity, by the magnetic field of the magnet in Example, as compared with Comparative example.

15 DESCRIPTION OF THE REFERENCE SYMBOLS

- 1 substrate to be deposited
- 10, 11 DLC film
- 90 outer shield
- 102 chamber
- 20 103 cathode electrode (cathode filament)
- 104 anode electrode (anode cone)
- 105 cathode power source (alternating current power source)
- 106 earth
- 25 107 anode power source (DC (direct current) power source)
- 108 inner shield
- 109, 119, 129 magnet

- 109a plasma state
- 119a, 129a magnetic field
- 112 bias power source (DC power source)
- 118 film thickness-correcting plate

CLAIMS:

1. A plasma CVD apparatus, comprising:
 - a chamber;
 - an anode disposed in said chamber;
 - 5 a cathode disposed in said chamber;
 - a holding part that is disposed in said chamber and holds a substrate to be deposited disposed so as to face said cathode and said anode;
 - an inner shield that is disposed in said chamber and
 - 10 is provided so as to cover spaces between said substrate to be deposited held by said holding part and each of said anode and said cathode;
 - a magnet disposed in said chamber, disposed outside said inner shield and disposed so as to surround said inner
 - 15 shield;
 - a first direct current power source electrically connected to said anode;
 - an alternating current power source electrically connected to said cathode;
 - 20 a second direct current power source electrically connected to said substrate to be deposited held by said holding part;
 - a gas-supplying mechanism for supplying a raw material gas into said chamber; and
 - 25 an exhaust mechanism for exhausting an inside of said chamber;
- wherein distance between a plane that is parallel to

a surface of said substrate to be deposited and includes an end part of said magnet on a side of said substrate to be deposited and a surface of said substrate to be deposited is from 15 mm to 100 mm.

5

2. The plasma CVD apparatus according to claim 1, wherein:
said inner shield is surrounded by $2n$ magnets; and
in each of said $2n$ magnets, either an N pole or an S pole faces an inside of said inner shield, and in said magnets
10 adjacent to each other, magnetic poles facing the inside of said inner shield are opposite to each other,
where n is an integer of 2 to 12.

3. The plasma CVD apparatus according to claim 2, wherein
15 a magnetic field in an outer periphery of said substrate to be deposited is from ± 0.1 G to ± 50 G.

4. The plasma CVD apparatus according to claim 1, wherein;
said inner shield is surrounded by one magnet; and
20 in said one magnet, either an N pole or an S pole faces a side of said cathode and the other of the N pole or the S pole faces a side of said substrate to be deposited.

5. The plasma CVD apparatus according to any one of claims
25 1 to 4, wherein:

the apparatus has an outer shield that is disposed in said chamber and is disposed outside said inner shield; and

said magnet is positioned outside said outer shield.

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

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

in said chamber, said raw material gas is put into a plasma state by discharge between said cathode and said anode, and the plasma is accelerated and bombarded on a surface of the substrate to be deposited held by said holding part to form a protective layer having carbon as a main component.

7. A method for manufacturing a magnetic recording medium in which at least a magnetic layer is formed on a nonmagnetic substrate, and after that, a protective layer having carbon as a main component is formed, wherein

the plasma CVD apparatus according to any one of claims 1 to 5 is used to form said protective layer.