

METHOD AND APPARATUS FOR FORMING HARD CARBON FILM

Technical Field

The present invention relates to a method of forming a hard carbon film used as a coating of a sliding resistant member or wear resistance member of each of various kinds of metal molds, mechanical parts, tools, etc. and as a protection film of a magnetic recording medium, and an apparatus used for the method.

Background Art

When sliding resistant members and wear resistance members for various kinds of metal molds, mechanical parts, tools are manufactured, various kinds of hard coatings are coated on the surfaces of substrates formed of super alloy or ceramic materials from the viewpoint of high-quality and/or long lifetime of products. Furthermore, it is also general to coating the surface of a magnetic recording medium such as a hard disc or the like with a hard coating as a protection film.

Diamond-like carbon (DLC) film based on a plasma CVD method or sputtering method is known as a hard coating using carbon in the hard coatings used for the above purpose. In this technique, a film of 10GPa or more in hardness is called

as DLC film. Furthermore, the DLC film is more excellent in surface smoothness as compared with polycrystal thin film such as titan nitride or the like because it is amorphous and has no crystal grain boundary, and thus it is a suitable material as a surface coating. Therefore, the DLC film is generally used as a protection film of a magnetic recording medium by taking advantage of such a characteristic as described above, and also it is known as film providing excellent sliding characteristic in spite of the film thickness of 100nm or less.

Recently, it has been required from the market side to further enhance the sliding resistance performance and the wear resistance performance, and hard coatings which are more excellent in sliding resistance performance and wear resistance performance than the DLC film have been required. Particularly in the case of magnetic recording media, the distance between a read-write head and a medium has been required to be reduced in connection with increase in recording density, and there has been required a protection film which is thin in thickness, but has excellent sliding resistance performance.

A method using carbon ions is known as a method of forming a harder and more delicate carbon film. According to this

method, carbon or hydrocarbon gas is decomposed by plasma, and a film is formed by controlling the energy of carbon ions or hydrocarbon ions thus occurring. At this time, it is necessary to exclude deposition of neutral atoms/radicals and fine particles as much as possible in order to achieve excellent film quality. A filtered cathodic arc (FCA) method is known as one of these methods (see Patent JP-A-2002-285328).

According to the FCA method, arc discharge is started between a cathode 6 having a deposition material 7 mounted therein and an anode 5 under vacuum by using a striker 8. A part of the deposition material 7 vaporizes at a local area (cathode spot) and forms plasma 11 containing deposition material ions together with neutral atoms/molecules, radicals and fine particles. Only charged electrons and deposition ions in the plasma 11 are accelerated by an electric field applied between the anode 5 and the cathode 6, and led to a substrate 2 in a film forming chamber 1 by magnetic field of a solenoid coil 4 to thereby prevent contamination of the neutral atoms/molecules, radicals and fine particles into the film. Specifically, the electrons and the deposition material ions are led along the lines of magnetic force occurring by the curved solenoid coil 4, and arrive at the substrate 2. On the other hand, non-charged vaporized materials go straightly, and thus they do not arrive at the substrate 2.

When carbon is used as the deposition material, a film of a material called as tetrahedral amorphous carbon (ta-C) is formed. The ta-C film is very hard, and has hardness larger than DLC. Therefore, it is expected to be used as a protection film of a magnetic recording medium or magnetic read-write head.

Furthermore, there is disclosed a method of manufacturing a high-purity and excellent film by preventing direct impingement of electrons and ions occurring in a plasma chamber against an object to be treated in a plasma CVD method using ECR (see Patent Document 2). According to this method, a shielding member is equipped between a plasma high-density area and a substrate in a plasma chamber to prevent the impingement of ions and electrons against the substrate and damage of a coating by the impingement concerned. This method is different from the method using carbon ions in that film formation is carried out by neutral active species which are generated by the electrons occurring in the plasma in the film forming chamber. That is, this method is used to form diamond crystal films and amorphous Si films, and the characteristics of these films are deteriorated by ion impingement. Conversely, the present invention uses ions, and is suitable for the film formation of ta-C. Furthermore, the Patent JP-A-6-188206 discloses

that the shielding member is preferably non-magnetic material, and that using a solenoid coil around the film forming chamber magnetic field is generated so as to spread an electron stream from the plasma chamber, thereby forming a film having a larger area.

Furthermore, there is developed a plasma treatment apparatus in which in order to prevent pollution by a cathode material component discharged from a cathode, bucket type magnetic field is formed around the apparatus and a shielding member is disposed between the cathode and a treatment substrate (see Patent JP-A-7-41952). In this apparatus, the cathode material component discharged from the cathode is shielded by the shielding member, and plasma is led to the treatment substrate by the bucket type magnetic field, whereby a uniform plasma treatment can be performed. In this apparatus, it is neither disclosed nor suggested that the shielding member is a magnet.

Problem to be solved by the Invention

However, as shown in Fig. 1, the FCA method has a filter portion 3 containing a curved solenoid coil 4, and thus the apparatus has a large-scale structure. For example, the length of the filter portion 3 is increased to about 1m in some apparatuses. Furthermore, the vaporized material 7 is

not disposed at the front side of the substrate 2, and thus the symmetry (uniformity) of the film formed on the substrate 2 is degraded. Furthermore, a power source 9 for the solenoid coil is needed in addition to a power source 10 for arc discharge. In addition, a lot of fine particles occur because arc discharge is used, so that these fine particles may impinge against the inner wall of the filter portion 3 and scatter therefrom, thereby degrading the properties of the film achieved. Accordingly, it has been required to develop a method of forming a film having higher symmetry (uniformity) and an excellent characteristic by using a more compact apparatus.

In order to solve the above problem, an object of the present invention is to provide method and apparatus of forming a film by only ions. More specifically, an object of the present invention is to provide method and apparatus of forming a hard carbon film.

Means of solving the Problem

The present invention relates to a method of disposing shielding member formed of a magnet between a plasma source and a substrate and forming a film. By supplying gas-type raw material to the plasma source, a film can be formed on the substrate on the basis of the principle of the plasma CVD

method. Here, the plasma source is hidden by the shielding member, and disposed so that it is not viewed from the substrate. Particularly, it is preferable that a rotation symmetry is used as the shielding member, and the axis of the rotation is disposed in a direction linking the plasma source and the substrate. The magnet serving as the shielding member is disposed so that one of the magnetic poles thereof faces the plasma source and the other magnetic pole faces the substrate. Furthermore, a magnet may be further disposed at the opposite side of the substrate to the shielding member. The pressure in the film forming process is set to 1Pa or less, and a bias voltage may be applied to the substrate.

According to the above means, the plasma source can be disposed at the front side of the substrate, the symmetry of the film thus formed is enhanced, and the distance between the plasma source and the substrate can be shortened to about several tens cm. Furthermore, a permanent magnet may be used as the shielding member, and no power source for generating the magnetic field is needed.

Brief Description of the Drawings

Fig. 1 is a cross-sectional view showing an example of a film forming apparatus used in an FCA method.

Fig. 2 is a cross-sectional view showing an example of a film forming apparatus used in a plasma CVD method according to the present invention.

Fig. 3 are diagrams showing the cross-sections along the rotational axis of a rotation symmetry shielding member used in the method of the present invention, wherein (A) shows a cross-section of a shielding member having a cone-cylinder connected shape, (B) shows a cross-section of a shielding member having a cylindrical shape, (C) shows a cross-section of a shielding member having a double-cone shape, and (D) shows a cross-section of a shielding member having a oval shape.

Fig. 4 is a cross-sectional view showing an example of a film forming apparatus in which a second magnet is equipped at the back side of a substrate holder, which is used in another method of the present invention.

Best Modes for Carrying out the Invention

Embodiments according to the present invention will be described here under with reference to the accompanying drawings. Fig. 2 is a diagram showing an example of the construction of a plasma CVD apparatus used in this invention. A plasma source 22 is equipped to a part of a

vacuum chamber 21, and a substrate holder 23 for holding a substrate 26 is equipped in the vacuum chamber 21. The plasma source 22 is connected to a high-frequency power source 24, and the substrate holder 23 is connected to a DC power source 25. Furthermore, a shielding member 27 is disposed between the plasma source 22 and the substrate 23 so that the plasma source 22 cannot be viewed from the substrate 26.

The vacuum chamber 21 has a structure having a gas introducing port and an exhaust port (not shown) which is known in the technique concerned. Preferably, the vacuum chamber 21 is electrically grounded.

A hollow cathode type electrode is used as the plasma source 22 of the present invention. The plasma source 22 is electrically insulated from the vacuum chamber 21. In order to form a film having a uniform thickness on the substrate 26, the plasma source 22 is disposed so as to face the substrate holder 23.

The substrate holder 23 may have a design of any structure known in the technique concerned, which holds the substrate 26 so that the substrate 26 faces the plasma source 22 and may be equipped with means for applying a bias

voltage as occasion demands. The substrate holder 23 may be equipped with no substrate heating means.

A glass substrate, a ceramic substrate, an Si substrate, a hard metal substrate, a magnetic recording medium having a recording layer formed thereon or the like may be used as the substrate 26. The substrate 26 may be designed in a flat shape, or may be designed in a cubic shape required to sliding resistant members or wear resistant members for various kinds of metal molds, mechanical parts, tools, etc.

The shielding member 27 may be a permanent magnet or electromagnet. In order to exclude necessity of any power source for generating magnetic field, the shielding member 27 is preferably a permanent magnet. In this invention, in order to lead electrons and ions of raw material gas generated in the plasma source to the substrate, it is preferable that one of the magnetic poles of the shielding member is disposed to face the plasma source 22, and the other pole is disposed to face the substrate holder 23 (substrate 26).

The magnet forming the shielding member 27 may be formed of any material known in the technique concerned which contains alnico based material, Fe-Cr-Co based material, ferrite based material, rare earth type material (samarium

cobalt type (SmCo_5 , $\text{Sm}_2\text{Co}_{17}$ or the like), Nd-Fe type or the like). It is preferable that a magnet having a residual magnetic flux density of 0.1T or more is used as the shielding member 27 of the present invention to effectively induce plasma. The shielding member 27 of the present invention may be manufactured by molding the above material in a proper shape and then magnetizing it. Alternatively, the shielding member 27 may be manufactured by forming a rod-shaped magnet of the above material and then attaching a soft-magnetic material (silicon steel, soft ferrite or the like) to the tips of the magnetic poles of the magnet. The surface thereof may be coated with non-magnetic ceramic, polymer, metal or the like to prevent it from being damaged by plasma.

When the shielding member 27 is formed by using an electromagnet, it is formed by winding a conducting wire around a non-magnetic material (Al or the like) or soft magnetic material (silicate steel, soft ferrite or the like) having a desired shape and then connecting it to a DC power source. When the electromagnet is used, the material and the voltage to be applied are selected so that the electromagnet has a magnetic flux density of 0.1T or more at the magnetic poles thereof.

The shielding member 27 is disposed between the plasma

source 22 and the substrate 23, and designed to have such a shape that the plasma source 22 is not viewed from the substrate 26. In order to form a film having a uniform thickness on the substrate 26, it is preferable that the shielding member 27 has a cross section having high symmetry when viewed from the substrate 26, and it is more preferable that it has a rotation symmetry whose rotational axis corresponds to the axis linking the plasma source 22 and the substrate holder 23. Fig. 3 is a cross-sectional view taken along the rotational axis of the shielding member 27. Fig. 3(A) shows a shielding member designed in such a shape that the cross-section thereof has a combined shape of a rectangle and a triangle and a cylinder is joined to the bottom surface of a circular cone. Likewise, Fig. 3(B) shows a shielding member designed in a cylindrical shape having a rectangular cross-section, Fig. 3(C) shows a shielding member designed in a double-conical shape having a rhombic cross-section, and Fig. 3(D) shows a shielding member designed in a oval shape having an elliptic cross-section. The maximum diameter of the shielding member 27 is dependent on the diameter of the substrate 26 on which a film will be formed, the arrangement position of the shielding member 27 (the distance from the substrate 26 and the distance from the plasma source 22), etc., and it may be properly selected under the condition that the plasma source 22 cannot be viewed from the substrate 26.

The raw material gas is introduced from the gas introducing port (not shown) equipped to the vacuum chamber 21 into the vacuum chamber 21 under the control of a gas flow control device, and becomes plasma under high-frequency discharge from the plasma source 22. Any material which is known as forming a desired film in the technique concerned may be used as the raw material gas. For example, when a carbon coating is formed, hydrocarbon gas such as ethylene, methane, acetylene, toluene, benzene, propane or the like may be used.

The plasma contains the ions of the raw materials and also neutral atoms and radicals. In this invention, the neutral atoms and the radicals are prevented from arriving at the substrate 26 by the shielding member 27. However, under this state, the ions of the raw material gas to be formed as a film on the substrate 26 cannot arrive at the substrate 26. Therefore, according to the method of this invention, the ions of the raw material are led to the substrate 26 by using the shielding member 27 as a magnet and generating magnetic field around the shielding member 27.

When magnetic field occurs in the vacuum chamber 21, electrons move along magnetic flux while making a cyclotron motion like the electrons spiral around the magnetic flux,

and the ions of the raw material gas follow the electrons so that the electrical neutrality is kept. With this effect, the plasma has a characteristic of moving along the magnetic flux as a whole. Accordingly, when a magnet is disposed around a treatment chamber as disclosed in the JP-A-6-188206 to form spreading magnetic field, the plasma is far away from the substrate. On the other hand, the plasma can be positively led to the substrate by forming the shielding member 27 with the magnet according to the present invention.

Furthermore, it is preferable that the pressure in the vacuum chamber 21 during the film forming process is set to 1Pa or less. By setting the pressure as described above, the mean free path of the plasma (particularly, the ions of the raw material gas) can be sufficiently lengthened, and thus the ions of the raw material gas can arrive at the substrate without being scattered, so that a uniform film can be formed.

A negative voltage may be applied to the substrate holder 23 to lead the ions of the raw material gas to the substrate as occasion demands. The voltage to be applied is preferably set to -1000 to 0V. Particularly, it is preferably set to -400 to 0V to form a hard ta-C film. By using such a voltage, ions moving at a proper speed impinge against a film which has been

already formed, so that a graphite component (sp^2 composite carbon) is selectively sputtered or converted to a diamond component (sp^3 composite carbon) in the carbon film, thereby forming the ta-C film.

Furthermore, according to the plasma CVD method used in the present invention, a lot of fine particles which occur in the method using arc discharge such as the FCA method can be prevented from occurring, and thus this method is effective to form a film having an excellent characteristic such as uniformity or the like.

Another embodiment of the present invention will be described with reference to Fig. 4. In an apparatus of Fig. 4, a second magnet 28 is further disposed on the back surface of the substrate holder 23 of the apparatus of Fig. 1 (on the surface at the opposite side to the plasma source). The second magnet 28 is disposed so that the center thereof is coincident with the center of the substrate holder 23 and one of the magnetic poles thereof is disposed at the substrate holder 23 side while the other magnetic pole is disposed at the opposite side. The direction of magnetization occurring in the second magnet 28 is coincident with the direction of magnetization occurring in the shielding member 27. That is, when the magnetic pole of the shielding member 27 which is disposed so

as to confront the plasma source 22 is N-pole, the magnetic pole of the second magnet 28 at the substrate holder 23 side is set to N-pole. The second magnet 28 may be a permanent magnet or an electromagnet, however, it is preferably a permanent magnet to exclude necessity of a power for generating magnetic field. The second magnet 28 may be formed by using the material of the shielding member 27 described above. It is effective that the second magnet 28 has a (residual) magnetic flux density of 0.1T or more to effectively lead the plasma (particularly, the ions of the raw material gas) to the substrate 26. When a coating is formed by using the apparatus of Fig. 4, the coating can be also formed under the same film forming condition as when the apparatus of Fig. 1 is used.

Embodiment 1

A carbon film was formed by using the plasma CVD apparatus shown in Fig. 2. An Si substrate 26 of 50mm in diameter was secured onto a substrate holder 23, and disposed at the front side of the plasma source 22 so that the distance between the substrate 26 and the plasma source 22 was equal to about 25cm. As the shielding object 27 was used a cone-cylinder joined body formed of alnico which has a cross-section shown in Fig. 3(A). The residual magnetic flux density at the tip of the apex of the cone was equal to about 1T. The diameter of the bottom surface of the cone and the

cylinder of the joint body was equal to 50mm, and the height of the cone and the cylinder was equal to 50mm. The apex of the cone of the joint body is disposed at a position of about 5cm from the plasma source. The cone side of the shielding member 27 was set to N-pole and disposed so as to face the plasma source 22, and the bottom surface of the cylinder at the opposite side was set to S-pole and disposed so as to face the substrate 26. The shielding member 27 was kept to be electrically floated.

Subsequently, ethylene gas at a flow rate of 5cc/min was introduced as raw material gas into the vacuum chamber 21, and the pressure in the vacuum chamber was set to 0.1Pa. A high-frequency (frequency of 13.56MHz) of 100W in power was applied to the plasma source, and film formation was carried out for one hour to form a carbon film on the Si substrate. The hardness of the carbon coating thus achieved was measured by using the NanoIndenter.

Embodiment 2

A carbon coating was formed on an Si substrate by using the same method as the embodiment 1 except that a voltage of -100V was applied to the substrate holder 23.

Embodiment 3

A carbon coating was formed on an Si substrate by using the same method as the embodiment 1 except that a voltage of -200V was applied to the substrate holder 23.

Comparative Example 1

The film formation was carried out by using the same method as the embodiment 1 except that a non-magnetic Al shielding member having the same shape was used in place of the shielding member 27 of alnico. In this case, no carbon coating was formed on the Si substrate.

Comparative Example 2

A carbon coating was formed on an Si substrate by using the same method as the embodiment 1 except that no shielding member 27 was used.

Comparative Example 3

A carbon coating was formed on an Si substrate by using the same method as the comparative example 2 except that a voltage of -200V was applied to the substrate holder 23.

Comparative Example 4

The film formation was carried out by using the same method as the embodiment 1 except that a voltage of +100V was

applied to the substrate holder 23, however, no carbon coating was formed on the Si substrate.

Comparative Example 5

The film formation was carried out by using the method as the embodiment 1 except that the pressure in the vacuum chamber 21 was set to 1Pa, however, no carbon coating was formed on the Si substrate.

Table 1

First Table: film formation using cone-cylinder joint body

	EMBODIMENT 1	EMBODIMENT 2	EMBODIMENT 3	COMPARATIV E EXAMPLE 2	COMPARATIV E EXAMPLE 3
SUBSTRATE BIAS VOLTAGE (V)	0	-100	-200	0	-200
FILM THICKNESS (nm)	80	100	100	500	450
HARDNESS (GPa)	30	40	40	5	15

As is apparent from the above embodiments, a hard carbon film having an excellent hardness of 30GPa could be achieved by using the magnet having the shape corresponding to a cone-cylinder joint body as the shielding member. When the non-magnetic shielding member of the comparative example 1 was used, no carbon film was formed on the substrate, and thus it is apparent that use of a magnet as the shielding member is effective to lead plasma (particularly, the ions of the raw material gas for film formation) to the substrate. The hardness of the carbon coating when no shielding member was

used was equal to 5Gpa, and thus it was apparent that the carbon coating achieved was like polymer. Furthermore, the hardness of the carbon coating of the comparative example 3 when no shielding member was used was equal to 15GPa which was within the hardness range of the DLC film, however, it is remarkably lower than the hardness of the coating achieved in the embodiment 1. These results were estimated to indicate that neutral atoms, radicals, etc. from the plasma source impinged against the substrate during the film formation process and lowered the film quality because no shielding member was used.

Furthermore, as shown in the embodiment 2 and the embodiment 3, the film thickness was increased and the film hardness was enhanced by applying a negative bias voltage to the substrate holder 23. As compared with the comparative example 4 in which no carbon film was formed by applying a positive bias voltage, the negative bias voltage is more effective to lead the plasma (particularly, the ions of the raw material gas for film formation) to the substrate. Furthermore, it is apparent that the component contributing to the film formation is carbon ions.

Furthermore, in the comparison example 5 in which the pressure in the vacuum chamber was increased, no carbon film

could be formed on the substrate. This is estimated to occur because the increase of the pressure shortened the mean free path of the ions of the raw material gas and thus the film formation suffered a scattering effect.

Comparative Example 6

A carbon coating was formed by using the FCA apparatus shown in Fig. 1. A carbon block of 99.999% in purity, 30mm in diameter and 30mm in thickness was used as a cathode target 7. A water cooling type cooling means was equipped to the cathode 6 and the anode 5 to prevent over-heat during arc discharge. A magnetic filter 3 of a quarter arcuate stainless pipe of 76mm in diameter and 300mm in radius of curvature was used as a core pipe, and a copper wire coated with polyester coating of 2mm in diameter was wound around the core pipe to equip a filter coil 4. The number n of turns per unit length of the coating copper wire was set to 1000 turns/m. An Si substrate 2 was mounted in a film forming chamber 1 to be vertical to the axial direction of the magnetic filter. Under the state that a voltage of 40V was applied between the cathode and the anode, the striker 8 was brought into contact with the surface of the cathode target 7, and arc discharge was started. A cathode voltage during arch discharge was equal to -25V, and discharge current was set to 120A. Predetermined current was supplied to the magnetic filter

coil 4 so that the internal magnetic field in the magnetic filter was equal to 0.013T. The film formation was carried out for five minutes, and a Ta-C film of about 200nm in film thickness was achieved.

However, the position at which the maximum film thickness is provided was deviated from the center of the magnetic filter to the inner peripheral side, and it was deviated from the center of the substrate to the right side by about 25mm in Fig. 1. As the position was far away from this position, the film thickness was reduced, and the film thickness was reduced by about 50% on the circumference of a circle of 15mm in radius. However, the reduction of the film thickness was greater at the inner peripheral side of the filter, and the film thickness was reduced to be less at the inner peripheral side than at the outer peripheral side by about 10% on the circumference of 15mm in radius. On the other hand, with respect to the carbon coating achieved in the embodiment 1 and the comparative example 2, the center of the film thickness distribution was the center of the substrate, and the variation of the film thickness on the circumference of 15mm in radius was also within 5% of the maximum film thickness. This was because the film forming mechanism in the embodiment 1 and the comparative example 2 was axially symmetric. On the other hand, it is apparent

that the symmetry of the FCA apparatus was lost because it had the magnetic filter portion and thus the film thickness distribution was affected by the loss of the symmetry.

Embodiment 4

A carbon coating was formed on an Si substrate by using the same method as the embodiment 1 except that a shielding member having a cylindrical shape of 100mm in height which has a bottom surface of 50mm in diameter as shown in Fig. 3(B) was used in place of the shielding member 27 having the shape corresponding to the cone-cylinder joint body used in the embodiment 1. The intensity and position of the magnet of the shielding member were set to the same as the embodiment 1.

Embodiment 5

A carbon coating was formed on an Si substrate by using the same method as the embodiment 1 except that a shielding member having a double-cone shape in which the bottom surface thereof was 50mm in diameter and each cone was 100mm in height as shown in Fig. 3(C) was used in place of the shielding member 27 having the shape corresponding to the cone-cylinder joint body used in the embodiment 1. The intensity and position of the magnet of the shielding member were set to the same as the embodiment 1.

Embodiment 6

A carbon coating was formed on an Si substrate by using the same method as the embodiment 1 except that a shielding member having a flat-spherical shape of 50mm in maximum diameter and 100mm in length as shown in Fig. 3(D) was used in place of the shielding member 27 having the shape corresponding to the cone-cylinder joint body used in the embodiment 1. The intensity and position of the magnet of the shielding member were set to the same as the embodiment 1.

Table 2

Table 2: Effect of the shape of the shielding member 27

	EMBODIMENT 1	EMBODIMENT 4	EMBODIMENT 5	COMPARATIVE EXAMPLE 6
FILM THICKNESS (nm)	80	5	150	180
HARDNESS (GPa)	30	30	30	30

As is apparent from the above embodiments, the ions of the raw material gas can be effectively led to the substrate by the shielding member having the cone-cylinder joint body shape than the shielding member having the cylindrical shape, and the shielding member having the double-cone shape and further the shielding member having the flat-spherical shape are more effective.

Embodiment 7

A coil of a turning density of 4 turns/cm was wound round

the side surface of the non-magnetic Al shielding member used in the comparative example 1, and connected to a DC power source of 10A to form an electromagnet. A carbon coating was formed on an Si substrate by using the electromagnet according to the same method as the comparative example.

The carbon coating thus achieved had a film thickness of 30nm, and thus it is apparent that the ions of the raw material gas can be also led to the substrate by using the electromagnet.

Embodiment 8

A carbon coating was formed by using the plasma CVD apparatus shown in Fig. 4 in which the second magnet 28 was disposed at the back side of the substrate holder 23. The second magnet 28 was designed as a cylindrical magnet of 50mm in diameter and 100mm in length. The bottom surface of the second magnet was set to N-pole, and the bottom surface concerned was brought into contact with and secured to the substrate holder 23 (that is, the plasma surface side was set to N-pole). The other bottom surface of the second magnet was set to S-pole.

A carbon coating was formed on an Si substrate by using the same apparatus and method as the embodiment 1 except

that the second magnet 28 is disposed.

The film thickness of the carbon coating thus achieved was equal to 120nm, and thus comparing the film thickness of 80nm achieved in the embodiment 1, it is apparent that the second magnet 28 disposed at the back side of the substrate holder 23 has a function of leading the plasma (particularly, the ions of the raw material gas) more effectively.

Advantageous Effect of the Invention

According to the method of the present invention, the shielding member formed of a magnet is disposed between the plasma source and the substrate, and a film can be formed by only ions of raw material gas in plasma. In the method of the present invention, the plasma source can be disposed at the front side of the substrate, and film formation can be performed with higher symmetry and higher uniformity as compared with the FCA method. Furthermore, a permanent magnet is used as the shielding member, and thus a power source for supplying power to a solenoid coil which is indispensable for the FCA method is not required.

Furthermore, according to the method of the present invention, gas-type raw material is used as in the case of the normal plasma CVD method, and thus occurrence of a lot of

fine particles due to arc discharge can be avoided. As in the case of the FCA method, the acceleration energy of the ions of the raw material gas can be controlled by a bias voltage applied to the substrate, and a hard carbon coating can be formed.

The hard carbon coating achieved by the method and apparatus of the present invention is effectively used as a coating of a sliding resistant member or wear resistant member for various kinds of metal molds, mechanical parts, tools, etc., and as a protection film for a magnetic recording medium or magnetic recording head.

CLAIMS

1. A film forming plasma CVD method for decomposing a raw material in plasma and forming a film from the decomposed material, characterized in that a shielding member is disposed between a plasma source and a substrate and the shielding member is formed from a first magnet.

2. The film forming method according to claim 1, wherein the raw material is hydrocarbon gas, and the film to be formed is a carbon film.

3. The film forming method according to claim 1, wherein the method is executed under pressure of 1Pa or less.

4. The film forming method according to claim 1, wherein a voltage is applied to the substrate.

5. The film forming method according to claim 4, wherein the voltage is a negative voltage.

6. The film forming method according to claim 1, wherein a shield is formed out by the shielding member so that the plasma source is not viewed from the substrate.

7. The film forming method according to claim 1, wherein one of the magnetic poles of the shielding member is disposed to confront the plasma source, and the other is disposed to confront the substrate.

8. The film forming method according to claim 1, wherein the shielding member has a rotation symmetry, and the axis of the rotation is in a direction linking the plasma source and the substrate.

9. The film forming method according to claim 8, wherein the diameter of the shielding member is set to be larger than the diameter of the substrate.

10. The film forming method according to claim 1, wherein the shielding member is a permanent magnet.

11. The film forming method according to claim 1, wherein a second magnet is further disposed at the opposite side of the substrate to the shielding member, and the magnetization direction of the second magnet is the same as the first magnet.

12. The film forming apparatus, comprising a plasma source for decomposing a raw material, a substrate on which

the decomposed material is deposited, and a shielding member serving as a first magnet, wherein the shielding member is disposed between the plasma source and the substrate.

13. The film forming apparatus according to claim 12, further comprising means for applying a voltage to the substrate.

14. The film forming apparatus according to claim 13, wherein the voltage is a negative voltage.

15. The film forming apparatus according to claim 12, wherein a shield is formed out by the shielding member so that the plasma source is not viewed from the substrate.

16. The film forming apparatus according to claim 12, wherein one of the magnetic poles of the shielding member is disposed to confront the plasma source, and the other is disposed to confront the substrate.

17. The film forming apparatus according to claim 12, wherein the shielding member has a rotation symmetry, and the axis of the rotation is in a direction linking the plasma source and the substrate.

18. The film forming apparatus according to claim 17, wherein the diameter of the shielding member is set to be larger than the diameter of the substrate.

19. The film forming apparatus according to claim 12, wherein the shielding member is a permanent magnet.

20. The film forming apparatus according to claim 12, further comprising a second magnet disposed at the opposite side of the substrate to the shielding member, wherein the magnetization direction of the second magnet is the same as the first magnet.