

VACUUM ARC EVAPORATION APPARATUS, VACUUM ARC EVAPORATION METHOD AND MAGNETIC RECORDING MEDIUM

Technical Field

The present invention relates to a vacuum arc evaporation apparatus, a vacuum arc evaporation method and a magnetic recording medium, and more particularly in detail to a vacuum arc evaporation apparatus and a vacuum arc evaporation method that are used for forming a hard coating film used for coating for a wear resistant material or an abrasive resistant material, the hard coating film, and a magnetic recording medium having the hard coating film as a overcoat layer.

Background Art

Of the hard coating film used for coating for a wear resistant material or an abrasive resistant material, a diamond-like carbon (DLC) film is presented as that using carbon. The DLC film is excellent in surface smoothness and has high hardness, so that it is suited for a surface coating film.

For forming such a hard coating film, there has been used a method such as a sputtering method, a plasma CVD method or a vacuum arc evaporation method. In Fig. 1, there is shown

an example of an arrangement of a filtered cathodic arc (FCA) evaporation apparatus as an example of currently used vacuum arc evaporation apparatus.

In the example of the arrangement in Fig. 1, cathode material plasma P is generated at an arc source Sa. With the use of a magnetic filter 10, the plasma P is guided as a cathode material plasma beam Pb to a substrate to be coated 13 held in a deposition vacuum chamber 14 having a shutter 19. The magnetic filter 10 has a stainless steel pipe 11 bent in a quarter circular-arc-like shape as a core, on which an electromagnet coil 12 is provided. Between the magnetic filter 10 and the deposition vacuum chamber 14, a raster coil 18 is provided. With this arrangement, on the substrate to be coated 13, a film is formed from cathode material ions. When carbon (graphite) is used as the cathode material in the vacuum arc evaporation apparatus, it is known that the formed film becomes tetrahedral amorphous carbon (ta-C) containing no hydrogen, being rich in sp^3 bond carbon and having high hardness.

At the arc source Sa in the above arrangement, with a deposition material taken as a cathode target 16, vacuum arc discharge is induced between the cathode target 16 and an anode 17 by making a striker 15 in contact with the surface

of the cathode target 16 to thereby generate the cathode material plasma P. However, there was a problem that stable maintenance of the arc discharge was difficult. Moreover, there was another problem that a cathode spot of the discharge goes around the cathode target 16 to make the cathode material plasma beam Pb hard to be brought forward.

An example of an arrangement of the arc source Sa is shown in JP-A-2002-32907. Another example thereof is shown in JP-A-2002-88466.

Problems to be Solved by the Invention

However, for stably maintaining arc discharge, it is considered that the arrangement of the arc source and the method of generating the arc discharge must be further specialized. Furthermore, in the arrangement disclosed in JP-A-2002-88466, it was difficult to provide a cooling mechanism for a magnetic material.

It is an object of the invention to provide a vacuum arc evaporation apparatus provided with a vacuum arc discharging unit having a specialized arrangement that can actualize a specialized approach to stable maintenance of vacuum arc discharge at an arc source when deposition is carried out, a vacuum arc evaporation method of carrying out such vacuum

arc discharge and a magnetic recording medium having a overcoat layer with high hardness which film is formed by using the vacuum arc discharging unit.

Means for Solving the Problems

In order to achieve the above object, as an apparatus according to the invention, a vacuum arc evaporation apparatus was implemented which includes a deposition vacuum chamber to be evacuated; a discharging unit carrying out arc discharge with cathode target which is made from a deposition material for depositing a substrate disposed in the deposition vacuum chamber; and a plasma guiding unit disposed between the deposition vacuum chamber and the discharging unit, and used for guiding cathode material plasma generated by the arc discharge to the deposition vacuum chamber by an induced magnetic field generated by feeding a current to a coil of the plasma guiding unit to deposit the cathode material deposited on the substrate, wherein the discharging unit comprises an electrically grounded discharge vacuum chamber; the cathode target provided at a position away from the plasma guiding unit in the inside of the discharge vacuum chamber, the cathode target being ungrounded; a first generating unit provided in the inside of the discharge vacuum chamber between the plasma guiding unit and the cathode target for making a first magnetic field in a first

direction; and a second generating unit provided around the discharge vacuum chamber for making a second magnetic field in a second direction approximately opposite to the first direction in the inside of the discharge vacuum chamber.

In order to achieve the above object, as a method according to the invention, a vacuum arc evaporation method was implemented, with the use of the above-explained vacuum arc evaporation apparatus, by evacuating the deposition vacuum chamber containing a substrate, generating the cathode material plasma by carrying out arc discharge using the discharging unit with the cathode target which is made from the deposition material for depositing the substrate, and depositing the cathode material on the substrate by guiding the cathode material plasma to the deposition vacuum chamber by an induced magnetic field generated by feeding a current to a coil of the plasma guiding unit, thereby carrying out deposition of the substrate.

In order to achieve the above object, as a magnetic recording medium according to the invention, a magnetic recording medium was implemented which includes a substrate, a magnetic recording layer provided on the substrate, and an overcoat layer formed on the magnetic recording layer, wherein the overcoat layer is made up of a

film formed by using the above-explained vacuum arc evaporation apparatus.

Moreover, in order to achieve the above object, as the magnetic recording medium according to the invention, a magnetic recording medium was implemented which includes a substrate, a magnetic recording layer provided on the substrate, and a overcoat layer formed on the magnetic recording layer, wherein the overcoat layer is made up of a film formed by employing the above-explained vacuum arc evaporation method.

Brief Description of the Drawings

Fig. 1 is a view showing an example of an arrangement of a currently used vacuum arc evaporation apparatus.

Fig. 2 is a view showing an arrangement of a principal part of the best mode of a vacuum arc evaporation apparatus according to the invention.

Best Mode for Carrying Out the Invention

Figure 2 is a view showing an arrangement of a principal part of the best mode of a vacuum arc evaporation apparatus according to the invention. The other part (the part on the left side of a magnetic filter 10 shown by broken

lines in the figure) of the vacuum arc evaporation apparatus has the same arrangement as that shown in Fig. 1.

In an arc source Sa, a cylindrical stainless pipe with an outer diameter of 76mm and an inner diameter of 70mm was used as a main body of an arc source vacuum chamber 1. The arc source vacuum chamber 1 was electrically grounded (not shown). For a cathode 2 of the arc source Sa, a cylindrical graphite (carbon) at a purity of 99.999% with a diameter of 30mm and a length of 30mm was used, which was installed inside the arc source vacuum chamber 1 while being arranged so as not to be electrically grounded. Along with this, the cathode 2 is connected to a dc arc power supply Es2. An anode 3 is a copper tube having a diameter of 4mm formed in a coil-like shape with a length l of a winding portion being $l = 60\text{mm}$ and the number of winding of 9 turns, which was installed inside the arc source vacuum chamber 1 while being arranged so as not to be electrically grounded. Along with this, the anode 3 is connected to a dc arc power supply Es2. An arc current flowing in the coil-like anode 3 generates a magnetic field in the direction A toward the anode 3 from the cathode 2.

Moreover, a striker 4 is provided together with a striker power supply Es1. The striker 4 is in the ground

potential and is provided for starting the arc discharge while being made in contact with the surface of the cathode 2. The cathode 2, the anode 3 and the arc source vacuum chamber 1 are water-cooled so as to be prevented from being overheated when the arc discharge is carried out. Reference numerals 5a and 5b denote copper tubes for circulating water for cooling the anode 3. The copper tube 5a is also used for connecting the anode 3 and the dc arc power supply Es2. Reference numerals 6a and 6b denote water-cooling spaces for circulating water for cooling the arc source vacuum chamber 1.

Around the arc source vacuum chamber 1, a Helmholtz-coil-like external coil is installed which includes an around-cathode coil 7 and an around-anode coil 8 for generating a magnetic field in the inside of the arc source vacuum chamber 1. Furthermore, between the inner peripheral surface of the arc source vacuum chamber 1 and the anode 3, quartz glass 9 is arranged as an insulating material.

The magnetic filter 10 (similarly arranged to that shown in Fig. 1) is an electromagnetic coil with a quarter circular-arc-like stainless steel pipe, having an outer diameter of 76mm, an inner diameter of 70mm and a radius of curvature of 300mm, taken as a core, on which a polyester

covered copper wire having a diameter of 2mm is wound. Number of turns per unit length of the winding of the electromagnetic coil is 1000 turns/m.

As is apparent from Fig. 2 and the above explanation, the vacuum arc deposition apparatus in the best mode has an arrangement in which the magnetic filter 10 and the arc source Sa are provided independently of each other. Therefore, the magnetic field generated by the magnetic filter 10 exerts no adverse effect on maintenance of the arc discharge. In other word, enhancement of transport efficiency of the plasma and maintenance of the plasma discharge can be independently controlled to make it possible to stably maintain the vacuum arc discharge at the arc source for carrying out excellent deposition.

Examples of the vacuum arc evaporation method, carried out by using the vacuum arc evaporation apparatus with the above arrangement, will be explained in the following.

Example 1

An arc discharge was started by operating the striker 4 with a magnetic field of about 0.002T being generated between the cathode 2 and the anode 3 in the direction toward the cathode 2 from the anode 3 (opposite to the direction

A) by feeding a specified current to the Helmholtz-coil-like external coil including the around-cathode coil 7 and the around-anode coil 8. The arc voltage and current were 30V and 120A, respectively, with the magnetic field generated at the coil-like anode 3 being about 0.02T.

At this time, after the arc discharge was started by operating the striker 4, even though the voltage of the striker power supply Es1 was then turned off, the arc discharge could be stably maintained between the cathode 2 and the anode 3. Furthermore, no cathode spot of the discharge went around the cathode target (cathode 2) to allow a carbon material plasma to be guided by the magnetic filter 10 to a deposition chamber (not shown). Thus, a tetrahedral amorphous carbon film could be deposited for a desired time on a substrate to be coated (not shown) in the deposition chamber.

Example 2

In the apparatus in the best mode shown in Fig. 2, a test was carried out with a magnetic field of about 0.001T being generated between the cathode 2 and the anode 3 in the direction toward the cathode 2 from the anode 3 (opposite to the direction A) by feeding a current only to the around-cathode coil 7 or to the around-anode coil 8 of the

around-cathode coil 7 and the around-anode coil 8 included in the Helmholtz-coil-like external coil. The other conditions were the same as those in the example 1.

In any of the cases, after the arc discharge was made started by operating the striker 4, even though the voltage of the striker power supply Es1 was then made turned off, the arc discharge could be stably maintained between the cathode 2 and the anode 3. Furthermore, no cathode spot of the discharge went around the cathode target (cathode 2) to allow the carbon material plasma to be guided by the magnetic filter 10 to the deposition chamber (not shown). Thus, the tetrahedral amorphous carbon film could be deposited for a desired time on the substrate to be coated (not shown) in the deposition chamber.

Comparison Example 1

In the apparatus in the best mode shown in Fig. 2, a test was carried out with no current being fed to the Helmholtz-coil-like external coil including the around-cathode coil 7 and the around-anode coil 8. The other conditions were the same as those in the example 1.

In this case, arc discharge could be made started by operating the striker 4. However, when the voltage of the

striker power supply Es1 was made turned off, the arc discharge had stopped.

Comparison Example 2

In the apparatus in the best mode shown in Fig. 2, a test was carried out with a current being fed to the Helmholtz-coil-like external coil including the around-cathode coil 7 and the around-anode coil 8 so that a magnetic field was made generated in the direction toward the anode 3 from the cathode 2 (in the direction A). The other conditions were the same as those in the example 1.

In the comparison example 2, in any of the respective cases of feeding a current to both of the around-cathode coil 7 and the around-anode coil 8, to only the around-cathode coil 7, and to only the around-anode coil 8, even the starting of the arc discharge was impossible by operating the striker 4.

Comparison Example 3

In the apparatus in the best mode shown in Fig. 2, a test was carried out with a magnetic field being made generated by feeding a current to the Helmholtz-coil-like external coil including the around-cathode coil 7 and the around-anode coil 8 so that the magnetic field generated by the around-cathode coil 7 and the magnetic field generated by the around-anode

coil 8 are in directions facing each other or away from each other. The other conditions were the same as those in the example 1.

In any of the cases, arc discharge could be started by operating the striker 4. However, when the voltage of the striker power supply Es1 was turned off, the arc discharge had stopped.

Example 3

With a vacuum arc deposition method in either the example 1 or 2 used and with a disk, disposed in the deposition vacuum chamber (not shown) and formed so far as a magnetic recording layer, taken as a substrate to be coated (not shown), a overcoat layer was formed on the disk, by which a magnetic recording medium could be manufactured.

The overcoat layer formed in this way used graphite (carbon) as the cathode material to therefore permit the film to be provided as that made up of a tetrahedral amorphous carbon film containing no hydrogen, being rich in sp^3 bond carbon and having high hardness.

Advantageous Effect of the Invention

According to the invention, a vacuum arc evaporation apparatus was provided which includes a deposition vacuum chamber to be evacuated, a discharging unit carrying out arc discharge with a cathode target which is made from a deposition material for depositing a substrate disposed in the deposition vacuum chamber, and a plasma guiding unit disposed between the deposition vacuum chamber and the discharging unit, and used for guiding cathode material plasma generated by the arc discharge to the deposition vacuum chamber by an induced magnetic field generated by feeding a current to a coil of the plasma guiding unit to deposit the cathode material deposited on the substrate. In the apparatus, the discharging unit includes the cathode target being electrically ungrounded and made up of the deposition material, an anode being electrically ungrounded and provided as the first generating unit arranged between the cathode target and the plasma guiding unit to generate the first magnetic field by feeding a current for the arc discharge, a unit for supplying power for the arc discharge, a unit for starting the arc discharge, the discharge vacuum chamber electrically grounded in which the constituents described above are arranged and connected, and a unit for generating a magnetic field as the second generating unit provided around the discharge vacuum chamber for generating

the second magnetic field. The unit for generating a magnetic field generates the second magnetic field in the discharge vacuum chamber in the direction approximately opposite to the direction of the first magnetic field generated by the anode. This gives the effect of enabling stable maintenance of vacuum arc discharge at the arc source when carrying out deposition.

Claims

1. A vacuum arc evaporation apparatus comprising:

a deposition vacuum chamber to be evacuated;

a discharging unit carrying out arc discharge with a cathode target which is made from a deposition material for depositing a substrate disposed in the deposition vacuum chamber; and

a plasma guiding unit disposed between the deposition vacuum chamber and the discharging unit, and used for guiding cathode material plasma generated by the arc discharge to the deposition vacuum chamber by an induced magnetic field generated by feeding a current to a coil at the plasma guiding unit to deposit the cathode material on the substrate,

wherein said discharging unit comprises:

an electrically grounded discharge vacuum chamber;

the cathode target provided at a position away from the plasma guiding unit in the inside of the discharge vacuum chamber, the cathode target being ungrounded;

a first generating unit provided in the inside of the discharge vacuum chamber between the plasma guiding unit and the cathode target for making a first magnetic field in a first direction, the first generating unit being an anode; and

a second generating unit provided around the discharge vacuum chamber for making a second magnetic field in a second

direction approximately opposite to the first direction in the inside of the discharge vacuum chamber.

2. The vacuum arc evaporation apparatus according to claim 1, wherein the first direction is approximately the same as the direction toward the first generating unit from the cathode target, and the second direction is approximately the same as the direction toward the cathode target from the first generating unit.

3. The vacuum arc evaporation apparatus according to claim 1, wherein the first generating unit is an electrically ungrounded coil-like anode provided along the inside of the discharge vacuum chamber, and the direction of the center axis of the coil-like anode is approximately in parallel with the direction from the cathode target to the first generating unit.

4. The vacuum arc evaporation apparatus according to claim 1, wherein the second generating unit is a coil provided along the outside of the discharge vacuum chamber, and the direction of the center axis of the coil is approximately in parallel with the direction from the cathode target to the first generating unit.

5. The vacuum arc evaporation apparatus according to claim 1, wherein the discharge vacuum chamber has a tube-like shape and is provided with an insulating material between the inner surface of the discharge vacuum chamber and the first generating unit.

6. The vacuum arc evaporation apparatus according to claim 1, wherein a cooling unit is provided for preventing the cathode target, the first generating unit and the discharge vacuum chamber from being overheated by the arc discharge.

7. The vacuum arc evaporation apparatus according to claim 1, wherein the deposition material is carbon.

8. A magnetic recording medium comprising a substrate, a magnetic recording layer provided on the substrate, and a overcoat layer formed on the magnetic recording layer,

wherein the overcoat layer is made up of a film formed by using the vacuum arc evaporation apparatus according to claim 1.

9. A magnetic recording medium comprising a substrate, a magnetic recording layer arranged on the substrate, and a overcoat layer formed on the magnetic recording layer,

wherein the overcoat layer is made up of a tetrahedral amorphous carbon film with high hardness formed by using the vacuum arc evaporation apparatus according to claim 7.

10. A vacuum arc evaporation method comprising steps of; providing vacuum arc evaporation apparatus according to claim 1, evacuating the deposition vacuum chamber containing a substrate, generating the cathode material plasma by carrying out arc discharge using the discharging unit with the cathode target which is made from the deposition material for depositing the substrate, and depositing the cathode material on the substrate by guiding the cathode material plasma to the deposition vacuum chamber by an induced magnetic field generated by feeding a current to a coil of the plasma guiding unit, thereby carrying out deposition of the substrate.

11. The vacuum arc evaporation method according to claim 10, wherein the deposition material is carbon.

12. A magnetic recording medium comprising a substrate, a magnetic recording layer provides on the substrate, and a overcoat layer formed on the magnetic recording layer,

wherein the overcoat layer is made up of a film formed by carrying out the vacuum arc evaporation method according

to claim 10.

13. A magnetic recording medium comprising a substrate, a magnetic recording layer provided on the substrate, and a overcoat layer formed on the magnetic recording layer,

wherein the overcoat layer is made up of a tetrahedral amorphous carbon film with high hardness formed by carrying out the vacuum arc evaporation method according to claim 11.