

Description

Title of Invention

FILM FORMATION METHOD

Technical Field

[0001] The present invention relates to a film formation method of forming a coating film excellent in plasma resistance on a surface of a substrate.

Background Art

[0002] Conventionally, a material having excellent plasma resistance has been required for a member used in an environment exposed to plasma such as a semiconductor manufacturing apparatus. Patent Literature 1 discloses a technique of forming an yttrium oxide (Y_2O_3) film on a surface of a substrate by a thermal spraying method in order to obtain such a material. In this technique, by plasma spraying using Y_2O_3 powder as a raw material, yttrium oxide is formed in a film shape on a surface of a member in which damage due to plasma is a problem.

[0003] On the other hand, in recent years, forming an yttrium oxide film on a substrate by a vacuum film formation method (physical vapor deposition (PVD method)) has been studied. In such a PVD method, since a film is formed on the substrate by using an ionized material, a dense coating film can be formed as compared with a thermal spraying method which may cause defects in the film. In general, in the PVD method, it is known that a certain proportion of evaporated atoms is ionized to become ions. Therefore, it is possible to control the denseness and film characteristics (crystal structure and mechanical characteristics) of the coating film by applying a voltage (bias) to the substrate to be formed and changing the incident ion energy.

[0004] Among PVD methods, an arc ion plating (AIP) method is a film forming method based on evaporation and ionization of a cathode material by vacuum arc discharge under conditions of a large current (several tens to several hundreds of A) and a low voltage. In this case, in a case where an insulating material such as an oxide is deposited, it is necessary to perform reactive deposition in an atmosphere containing oxygen by using a metal target. At this time, since a discharge surface of a cathode is oxidized, if there is an area where arc discharge does not occur on the cathode surface, an oxide is deposited on the area, the area is widened, and it is likely to be difficult to continue the discharge. In order to solve this problem, Patent Literature 2 discloses that stable discharge can be performed by using an evaporation source having a weak magnetic field of 3 gauss to 50 gauss. Patent Literature 3 discloses that a bipolar pulse is applied by using this technique to form an oxide under conditions in pure oxygen. The same document discloses that a film is formed by a method in which an oxide containing Zr, Cr, Mo, Al, Si, Fe, Co, Ni, and Y is superimposed on a DC current by a large current pulse arc.

Citation List

Patent Literature

[0005] Patent Literature 1: JP 2001-164354 A

Patent Literature 2: JP 5306198 B2

Patent Literature 3: JP 5877147 B2

[0006] The present inventor has intensively attempted to form a Y_2O_3 film under an oxygen atmosphere by using the method disclosed in Patent Literature 2, but has found that there is a problem that an oxide is formed on a target surface during long-time discharge, and discharge is eventually impossible. The large current pulse arc as described in Patent Literature 3 has a problem that it is industrially difficult to apply because the power supply system is more complicated and expensive than a normal DC power supply.

Summary of Invention

[0007] An object of the present invention is to provide a film formation method capable of stably maintaining discharge during film formation in stably forming a conductive yttrium oxide film on a substrate by using an arc ion plating method.

[0008] In order to achieve the above object, the inventor of the present application has found a new film formation method as a result of repeating intensive experiments in order to form a conductive yttrium oxide film.

[0009] A film formation method of the present invention is a film formation method of forming, by an arc ion plating method, an yttrium oxide film on a substrate that is an object on which a film is to be formed, the method including disposing, in a chamber, a target including yttrium and the substrate, introducing at least oxygen into the chamber, applying a prescribed bias voltage to the substrate, evaporating a surface of the target in oxygen to form the yttrium oxide film on the substrate, and setting an oxygen partial pressure in the chamber during the evaporation to less than 0.4 Pa such that an O/Y ratio that is a ratio of oxygen to yttrium in the yttrium oxide film on the substrate is 1.5 or less.

Brief Description of Drawings

[0010] [FIG. 1] FIG. 1 is a schematic diagram showing a schematic configuration of a film formation apparatus for performing a film formation method according to one embodiment of the present invention.

[FIG. 2] FIG. 2 is a graph showing a relationship between an O/Y ratio, which is a ratio of oxygen to yttrium in an yttrium oxide film on a substrate, and electric resistance of the yttrium oxide film in Example of the present invention.

[FIG. 3] FIG. 3 is a graph showing a relationship between an oxygen flow rate and an oxygen partial pressure in Example of the present invention.

[FIG. 4] FIG. 4 is a graph showing a relationship between the oxygen partial pressure and the discharge voltage in Example of the present invention.

[FIG. 5] FIG. 5 is a graph showing a relationship between the oxygen partial pressure and the discharge voltage in Example of the present invention.

[FIG. 6] FIG. 6 is a graph showing surface roughness of the yttrium oxide film formed by changing the oxygen partial pressure in Example of the present invention.

[FIG. 7] FIG. 7 is a graph showing a change in oxygen partial pressure during long-time discharge in Example of the present invention.

[FIG. 8] FIG. 8 is a graph showing a change in discharge voltage during long-time

discharge in Example of the present invention.

[FIG. 9] FIG. 9 is a graph showing the O/Y ratio of the yttrium oxide film formed by changing the oxygen partial pressure in Example of the present invention.

Description of Embodiments

[0011] Hereinafter, an embodiment of the present invention will be described in detail with reference to the accompanying drawings. FIG. 1 is a schematic diagram showing a schematic configuration of a film formation apparatus 10 for performing a film formation method according to one embodiment of the present invention. The film formation method according to the embodiment of the present invention is a method of forming a coating film excellent in plasma resistance on a surface of a substrate.

[0012] The film formation apparatus 10 shown in FIG. 1 is an example of a film formation apparatus for performing the film formation method according to the embodiment of the present invention, and the film formation apparatus for performing the film formation method is not limited to the apparatus shown in FIG. 1. The film formation apparatus 1 is an apparatus that forms a coating film on a surface of a workpiece W (substrate) disposed in a vacuum chamber 2 by using a physical vapor deposition method (PVD method). Examples of the film formation apparatus 1 include an AIP apparatus that performs film formation by using an arc ion plating method, and a sputtering apparatus that performs film formation by using a sputtering method.

[0013] The film formation apparatus 10 is an arc ion plating apparatus. The film formation apparatus 10 includes a vacuum chamber 12, a rotary table 14, a plurality of substrate holders 16, a bias power supply 18, a target 20 as an evaporation source, an arc power supply 22, a heater 24, an argon tank 30, an oxygen tank 32, a vacuum pump P, and a controller 50.

[0014] The vacuum chamber 12 accommodates the rotary table 14 and the plurality of substrate holders 16 disposed on the rotary table 14. The inside of the vacuum chamber 12 (that is, a space in which the rotary table 14 and the plurality of substrate holders 16 are accommodated) is maintained in a vacuum state or a state close to the vacuum state by the vacuum pump P in various steps including a film formation step. The vacuum chamber 12 is provided with a gas introduction port 12A and an exhaust port 12B.

[0015] The rotary table 14 has a disk shape including a center line extending vertically in FIG. 1. The rotary table 14 is disposed in the vacuum chamber 12. In the film formation step, the rotary table 14 rotates about its center line 16 while supporting the plurality of substrate holders 16. The rotary table 14 may further include a rotary table on which each of the plurality of substrate holders 16 is individually disposed so that each of the plurality of substrate holders 16 can rotate. The number of the substrate holders 16 is not limited to two as in FIG. 1.

[0016] Each of the plurality of substrate holders 16 supports the workpiece W that is an object on which a film is to be formed.

[0017] In the present embodiment, the workpiece W is disposed on an outer peripheral surface of the substrate holder 16. Note that FIG. 1 shows only some of the workpiece W.

[0018] In the present embodiment, the workpiece W includes alloy A6061 (Al alloy), and is a

square plate piece of 20 mm × 20 mm. Note that the material and the shape of the workpiece W is not limited to this example.

[0019] Each of the plurality of substrate holders 16 is formed with a conductive material. The conductive material is, for example, stainless steel.

[0020] The plurality of substrate holders 16 is disposed at equal intervals in a circumferential direction of the rotary table 14. In this state, a center line of each of the plurality of substrate holders 16 is parallel to the center line of the rotary table 14.

[0021] The bias power supply 18 applies a negative bias voltage to each of the plurality of substrate holders 16 via the rotary table 14. In the present embodiment, the bias power supply 18 intermittently applies a negative bias voltage to each of the plurality of substrate holders 16. That is, the bias power supply 18 is a pulse power supply. In a case where the resistance of the coating film formed on the workpiece W is relatively high, when a DC bias is applied as the bias voltage, a problem (charge-up) that charges are accumulated by incident ions may occur. On the other hand, as in the present embodiment, by applying a pulse voltage as the bias voltage, the problem can be suppressed even in a case where the resistance of the coating film formed on the workpiece W is relatively high. Specifically, by switching the bias between the negative side and the 0 V or positive side in the order of μ S or mS as the pulse voltage, the problem of the charge-up can be suppressed.

[0022] Note that the bias power supply 18 is not applied with a bias when a negative bias voltage is not applied in the film formation step. Alternatively, the bias power supply 18 can alternately apply a negative bias voltage and a positive bias voltage to each of the plurality of substrate holders 16. An absolute value of the negative bias voltage is greater than an absolute value of the positive bias voltage.

[0023] Note that, as long as the negative bias voltage and the positive bias voltage are alternately applied, the bias power supply 18 may be, for example, an alternating-current power supply (AC power supply) or a high-frequency power supply (RF power supply).

[0024] The target 20 is a disk-shaped member including yttrium. As an example, the target 20 is a disk having a diameter of 100 mm.

[0025] The arc power supply 22 is a DC power supply that functions as a discharge power supply that generates vacuum arc discharge in the target 20 disposed in the vacuum chamber 2. At this time, the target 20 functions as a cathode in the discharge. On the other hand, as shown in FIG. 1, the vacuum chamber 12 functions as an anode in the discharge. The target 20 receives discharge generated by the arc power supply 22 and emits yttrium ions evaporated from the surface of the target 20. Note that the arc power supply 22 constitutes an arc evaporation source together with the target 20.

[0026] The heater 24 is provided in the vacuum chamber 12, and generates heat by receiving current supplied from a heater power supply (not shown). As a result, the environment in the vacuum chamber 12 and the workpiece W are heated.

[0027] The argon tank 30 accommodates argon therein and supplies argon gas to the vacuum

chamber 12. Similarly, the oxygen tank 32 accommodates oxygen therein and supplies oxygen to the vacuum chamber 12. The amount of gas supplied from these tanks is controlled by adjusting an opening degree of a regulator (not shown) in response to a command from the controller 50. In another embodiment, the supply amount of gas may be adjusted manually by an operator.

[0028] The vacuum pump P brings an internal space of the vacuum chamber 12 into a vacuum state (vacuuming) through the exhaust port 12B.

[0029] In addition to the regulator described above, the controller 50 controls the rotation of the rotary table 14 and the like in addition to the control of the vacuum pump P, the control of various voltages or current values of the bias power supply 18, the arc power supply 22, and the heater 24.

Examples

[0030] Next, Examples of the film formation method according to the present embodiment will be described. In the following description, oxygen may be referred to as O, and yttrium may be referred to as Y. Note that the present invention is not limited to the range of following Examples.

[0031] <Example 1>

Hereinafter, Example 1 will be described. In executing the film formation method, as shown in FIG. 1, the target 20 and the workpiece W are attached in the film formation apparatus 10, and the inside of the vacuum chamber 12 is evacuated to a vacuum state by the vacuum pump P.

[0032] Next, after preheating is performed in the vacuum chamber 12 by the heater 24, argon gas is introduced from the argon tank 30 into the vacuum chamber 12 through the gas introduction port 12A, and bombardment is performed on the surface of the workpiece W by argon gas ion as pretreatment. Here, bombardment means that heavy inert gas ions such as argon ions are generated by plasma discharge, the surface of the workpiece W is heated by irradiating the workpiece W with the ions, and the surface is cleaned by the heating.

[0033] After the bombardment, pure oxygen gas is introduced at a flow rate of about 240 sccm so that the pressure in the chamber is about 1 Pa. In another embodiment, instead of the pure oxygen gas, an Ar-O₂ mixed gas (for example, Ar450 sccm and oxygen 50 sccm to 75 sccm) may be introduced so that the pressure in the chamber is about 2 Pa. In order to stably maintain the discharge, the total pressure in the chamber is desirably set in a range of 0.6 Pa or more and 4 Pa or less.

[0034] Next, the target 20 is discharged in the vacuum chamber 12 while functioning as a cathode to form an yttrium oxide film on the workpiece W. At this time, the temperature of the workpiece W during film formation is about 300°C (200°C or higher and 400°C or lower), an arc current is in a range of 100 A or higher and 150 A or lower, and the voltage applied to the workpiece W is a unipolar pulse with a frequency of 200 kHz, a duty of 56% or 300 kHz, and a duty of 60%, and the average voltage is changed between 10 V and 50 V. The film thickness of

the yttrium oxide film formed on the workpiece W is about 5 μm to about 100 μm . As described above, as an example, A6061Al (20 mm $\times$ 20 mm square piece shape) is used for the workpiece W. The amount of oxygen in the yttrium oxide film to be formed is controlled by changing the pressure of oxygen flowing into the chamber, that is, an oxygen partial pressure (oxygen flow rate).

[0035] Next, a method of evaluating the yttrium oxide film formed on the workpiece W will be described together with an index of the method.

[0036] (1) A test piece (workpiece W) formed with an O/Y ratio (the ratio of oxygen to yttrium in the yttrium oxide film on the workpiece W) was cut along the film thickness direction and embedded in a resin for evaluation, a cross section of the test piece was polished, then O and Y were measured at ten points in the film by using energy dispersive X-ray spectroscopy (EDX) from the sectional direction, and the O/Y ratio was calculated from an average value of the measurement.

[0037] (2) Electric resistance of yttrium oxide film

An electrode was brought into contact with each of a back surface and a front surface of the workpiece W (substrate), a voltage (3.5 mV to 350 mV, varied with resistance value) was applied between both electrodes, and the electric resistance of the film was calculated from the value of the current flowing at that time. For the measurement, a Milliohm high tester (HIOKI3540) was used.

[0038] FIG. 2 shows electric resistances of yttrium oxide films having different O/Y ratios. As described above, the O/Y ratio is controlled by changing the oxygen partial pressure (oxygen flow rate) in the chamber. As shown in FIG. 2, it was confirmed that when the O/Y ratio of the yttrium oxide film was less than 1.4, the electric resistance of the coating film rapidly decreased to have conductivity. Note that the O/Y ratio is more desirably set to 1.35 or less. In this case, the electric resistance of the yttrium oxide film can be stably maintained at 10,000 Ω or less. In this measurement, since an upper limit of the measured value of the resistance value of a measuring instrument is 30,000 Ω , all measurement points of 30,000 Ω in FIG. 2 indicate that the electric resistance is higher than that.

[0039] In a case where a film is formed with oxygen alone and the oxygen flow rate is small, the pressure in the chamber is lowered, the discharge voltage is increased, and the discharge tends to be unstable. Therefore, it is more desirable to further introduce Ar gas into the chamber and form a film under an Ar-O₂ atmosphere. As an example, in a case where only 50 sccm of oxygen was introduced into the chamber and discharge was performed, the pressure in the chamber was about 1×10^{-2} Pa and the discharge voltage was as high as 25 V, whereas in a case where 450 sccm of Ar gas and 50 sccm of oxygen gas were respectively introduced and the pressure in the chamber was 2.5 Pa, the discharge voltage was as low as about 17 V, and the discharge could be stably maintained. Note that Ar is more preferably introduced so that the pressure in the chamber at the time of discharge is 1 Pa or more.

[0040] The yttrium oxide film in the present invention is a state in which Y₂O₃ and Y are mixed

in the film, and the ratio of Y to O in the film changes as a result of changing the ratio of Y_2O_3 and Y. In the present invention, the film in which Y_2O_3 and Y are thus mixed is collectively referred to as “yttrium oxide film”. Note that the ratio of Y to O in this case is an atomic ratio. As an example, the film thickness of the yttrium oxide film on the workpiece W is 50 μm or more.

[0041] <Example 2>

Next, Example 2 will be described. In Example 2, too, the target 20 (diameter: 100 mm) including a metal Y was attached to an arc evaporation source of an arc ion plating apparatus (FIG. 1) connected with the arc power supply 22 including a DC power supply, and after evacuation and preheating, argon gas at 150 sccm or 450 sccm was introduced into the vacuum chamber 2. At this time, the introduction was performed such that the pressure (total pressure) in the vacuum chamber 2 was about 1 Pa to 2 Pa. Thereafter, a constant value (for example, 45 sccm) of pure oxygen gas was introduced, the arc evaporation source was discharged at a current of 100 A or more and 150 A or less for five minutes, and a transition of the discharge voltage at that time was measured. Thereafter, a step of increasing the amount of oxygen in the vacuum chamber 2 and further discharging for five minutes was repeated, and an experiment was performed up to an oxygen flow rate at which the discharge voltage rapidly increased.

[0042] FIG. 3 is a graph showing a relationship between the oxygen flow rate and the oxygen partial pressure of the oxygen introduced into the vacuum chamber 2 in Example 2. The oxygen partial pressure was calculated by multiplying the total pressure in the vacuum chamber 2 measured from a diaphragm type pressure gauge (manufactured by MKS) by the oxygen flow rate and dividing the resultant by a total gas flow rate (argon + oxygen). As shown in FIG. 3, it can be seen that the oxygen partial pressure changes substantially linearly with respect to the oxygen flow rate.

[0043] FIGS. 4 and 5 are graphs showing the relationship between the oxygen partial pressure and the discharge voltage in Example 2. FIG. 4 shows a result in a case where the arc current is 100 A, and FIG. 5 shows a result in a case where the arc current is 150 A. FIGS. 4 and 5 both show experiments at two levels (150 sccm or 450 sccm) for the introduction amount of argon gas.

[0044] As shown in FIGS. 4 and 5, it can be seen that the discharge voltage increases with the oxygen partial pressure, and the increase in the discharge voltage with respect to the increase in the oxygen partial pressure sharply increases at 0.3 Pa to 0.4 Pa. From the viewpoint of the discharge voltage, this phenomenon indicates that the discharge voltage is desirably 20 V or less in the system used in this experiment. Therefore, it has been found that it is necessary to control the oxygen partial pressure in the vacuum chamber 2 to at most less than 0.4 Pa in order to stably maintain discharge during film formation.

[0045] <Example 3>

Next, Example 3 will be described. In Example 3, too, the target 20 (diameter: 100

mm) including the metal Y was attached to the arc evaporation source of the arc ion plating apparatus (FIG. 1) connected with the arc power supply 22 including the DC power supply, and after evacuation and preheating, argon gas at 150 sccm was introduced into the vacuum chamber 2. At this time, the introduction was performed such that the pressure (total pressure) in the vacuum chamber 2 was about 2 Pa. Thereafter, pure oxygen gas was introduced, the arc evaporation source was discharged at a current of 125 A, and an yttrium oxide film was formed on an Si substrate (workpiece W) with a thickness of 3 μm as a target value. Note that a pulse bias (Voltage: -10 V, frequency: 200 kHz, pulse width: 2.8 μs) was applied during film formation. Then, surface roughness (Ra) of the formed film was measured with a probe type surface roughness meter (TOKYO SEIMITSU SURFCOM TOUCH550).

[0046] FIG. 6 is a graph showing the surface roughness of the yttrium oxide film formed by changing the oxygen partial pressure in Example 3. As shown in FIG. 6, since the surface roughness increases as the oxygen partial pressure decreases, and polishing or the like is required in practical use when the surface roughness increases, the surface roughness is desirably 0.4 μm or less. Therefore, it is desirable to set the oxygen partial pressure (x) = 0.17 Pa obtained by substituting Ra (y) = 0.4 into the regression equation ($y = -1.7628x + 0.6961$) based on the result of FIG. 6 as a lower limit value of the oxygen partial pressure. In this manner, the oxygen partial pressure during film formation is desirably set to 0.17 Pa or more.

[0047] <Example 4>

Next, Example 4 will be described. In Example 4, too, the target 20 (diameter: 100 mm) including the metal Y was attached to the arc evaporation source of the arc ion plating apparatus (FIG. 1) connected with the arc power supply 22 including the DC power supply, and after evacuation and preheating, argon gas at 450 sccm was introduced into the vacuum chamber 2. At this time, the introduction was performed such that the pressure (total pressure) in the vacuum chamber 2 was about 2 Pa. Thereafter, 50 sccm of pure oxygen gas was introduced, the arc evaporation source was discharged at a current of 100 A for 400 minutes, and the transition of the oxygen partial pressure and the discharge voltage in the vacuum chamber 2 was measured.

[0048] FIG. 7 is a graph showing a change in oxygen partial pressure during long-time discharge in Example 4. FIG. 8 is a graph showing a change in discharge voltage during long-time discharge in Example 4.

[0049] As shown in FIGS. 7 and 8, it can be seen that by controlling the oxygen partial pressure in the vacuum chamber 2 to less than 0.4 Pa, the discharge voltage was stabilized (20 V or less), and discharge for a long time became possible. It is to be noted that Examples 2 and 4 described above are intended to evaluate discharge characteristics, and a film was not actually formed.

[0050] As described above, when the discharge current (arc current) is 100 A or more and 150 A or less and the introduction amount of the argon gas is in a range of 150 sccm or more and 450 sccm or less, the oxygen partial pressure in the vacuum chamber 2 is adjusted in a range of less

than 0.4 Pa. Then, the discharge can be stably maintained.

[0051] <Example 5>

Next, Example 5 will be described. In Example 5, the target 20 (diameter: 100 mm) including the metal Y was attached to the arc evaporation source of the arc ion plating apparatus (FIG. 1) connected with the arc power supply 22 including the DC power supply, and after evacuation and preheating, bombardment was performed by argon gas ion. After this gas bombardment, a pure oxygen gas was introduced at about 1 Pa and a flow rate of about 240 sccm, or a mixed gas of argon and pure oxygen (Ar: 450sccm and oxygen: 50 sccm to 75 sccm) was introduced into the vacuum chamber 2 such that a total pressure was about 2 Pa. Then, the target 20 of the metal Y was discharged as a cathode to form an yttrium oxide film on the workpiece W. The temperature of the workpiece W during film formation was about 300°C, an arc current was between 100 A and 150 A, and the voltage applied to the workpiece W was a unipolar pulse with a frequency of 200 kHz, a duty of 56% or 300 kHz, and a duty of 60%, and the average voltage was changed between 10 V and 50 V. The thickness of the formed film is about 5 μm to about 100 μm . A6061Al (20×20 square) was used as the substrate of the workpiece W. The amount of oxygen in the yttrium oxide film was controlled by changing the oxygen partial pressure (oxygen flow rate) in the vacuum chamber 2.

[0052] FIG. 9 is a graph showing the O/Y ratio of the yttrium oxide film formed by changing the oxygen partial pressure in Example 5. Note that a method of calculating the O/Y ratio is similar to the method described above. As shown in FIG. 9, it can be confirmed that the yttrium oxide film formed with the oxygen partial pressure in a range of less than 0.4 Pa has O/Y of 1.5 or less (1.51 or less).

[0053] The embodiment of the present invention has been described in detail above. The yttrium oxide film obtained by the film formation method of the present invention can be widely applied to members exposed to plasma as represented by a semiconductor manufacturing apparatus and the like. In particular, by forming the yttrium oxide film by the arc ion plating method, it is possible to form a film that is dense and has high plasma resistance as compared with a case of film formation by a thermal spraying method.

[0054] The film formation method of the present invention is a film formation method of forming, by the arc ion plating method, the yttrium oxide film on the substrate that is an object on which a film is to be formed includes disposing, in the vacuum chamber 2, the target 20 including yttrium and the workpiece W (substrate), introducing at least oxygen into the vacuum chamber 2, applying a prescribed bias voltage to the workpiece W, evaporating the surface of the target 20 in oxygen to form the yttrium oxide film on the workpiece W, and setting the oxygen partial pressure in the vacuum chamber 2 during the evaporation to less than 0.4 Pa such that the O/Y ratio that is a ratio of oxygen to yttrium in the yttrium oxide film on the workpiece W is 1.5 or less.

[0055] In the present film formation method, the oxygen partial pressure in the vacuum chamber 2 during film formation is controlled by changing the amount of oxygen in the yttrium oxide film,

and thus, the electric resistance of the film can be reduced to obtain a conductive yttrium oxide film. In particular, since the oxygen partial pressure is set to less than 0.4 Pa, an oxide is less likely to be formed on the surface of the target 20, the discharge voltage can be prevented from rising, and a challenge of continuation of the discharge can be reduced.

[0056] The above method desirably further includes setting the oxygen partial pressure in the vacuum chamber 2 during the evaporation such that the O/Y ratio is less than 1.4. This method can further reduce the electric resistance of the film, and a conductive yttrium oxide film can be stably obtained.

[0057] The above method desirably further includes setting the oxygen partial pressure in the vacuum chamber 2 such that the electric resistance of the yttrium oxide film is 10,000 Ω or less. This method makes it possible to stably obtain a conductive yttrium oxide film having an electric resistance of 10,000 Ω or less by controlling the oxygen partial pressure during film formation and changing the amount of oxygen in the film.

[0058] The above method desirably further includes setting the oxygen partial pressure such that the discharge voltage during film formation is 20 V or less. This method can suppress a rise in an increase rate of the discharge voltage due to an increase in the discharge voltage by the oxygen partial pressure, and stably maintain the discharge during film formation.

[0059] The above method desirably further includes that the oxygen partial pressure is 0.17 Pa or more. This method can prevent film roughness of the film to be formed from increasing as the oxygen partial pressure decreases.

[0060] The above method desirably further includes introducing argon in addition to oxygen into the vacuum chamber 2. This method can reduce the discharge voltage during film formation and stabilize the discharge during film formation.

[0061] The above method desirably further includes applying a pulse voltage as the bias voltage to the workpiece W. Even in a case where the resistance of the coating film formed on the workpiece W is relatively high, this method can suppress charge-up in which charges are accumulated by the incident ions.

[0062] As the yttrium oxide film, it is desirable to obtain a film having a high electric resistance with an O/Y ratio of 1.4 or more and 1.5 or less. In this case, as described above, excellent discharge stability can be obtained by setting the oxygen partial pressure in the vacuum chamber 2 to less than 0.4 Pa such that the O/Y of the yttrium oxide film is 1.5 or less.

[0063] When the oxygen flow rate (oxygen partial pressure) is high during film formation, an oxide is formed on the surface of the target 20 including metal, the discharge voltage increases, and it is difficult to maintain the discharge. As in Examples above, since the increase rate of the discharge voltage tends to rise as the discharge voltage increases, it is desirable to adjust the oxygen flow rate (oxygen partial pressure) such that the discharge voltage is 20 V or less, more preferably 18 V or less. The oxygen partial pressure is preferably 0.17 Pa or more since the film roughness of the film to be formed increases as the oxygen partial pressure in the vacuum chamber 2 decreases.

[0064] Note that these configurations are merely examples, and the present invention is not to be construed as limiting in any way by the description of the above-described embodiment. In the present invention, the substrate is not limited to a substrate made of an insulating material, and may include a conductive material. In the present invention, the mode of alternately applying the negative bias voltage and the positive bias voltage is not limited to the pulse shape described in the above embodiment, and may be, for example, a sine wave shape. When the arc current is excessively small, discharge may not be stable, and when the arc current is large, the target may be heated. Therefore, for a target having a diameter of about 100 mm, it is desirable to set the arc current in a range of 50 A or more and 200 A or less.

[0065] A film formation method of the present invention is a film formation method of forming, by an arc ion plating method, an yttrium oxide film on a substrate that is an object on which a film is to be formed, the method including disposing, in a chamber, a target including yttrium and the substrate, introducing at least oxygen into the chamber, applying a prescribed bias voltage to the substrate, evaporating a surface of the target in oxygen to form the yttrium oxide film on the substrate, and setting an oxygen partial pressure in the chamber during the evaporation to less than 0.4 Pa such that an O/Y ratio that is a ratio of oxygen to yttrium in the yttrium oxide film on the substrate is 1.5 or less.

[0066] In this method, the oxygen partial pressure in the chamber during film formation is controlled by changing the amount of oxygen in the yttrium oxide film, and thus, the electric resistance of the film can be reduced to obtain a conductive yttrium oxide film. In particular, since the oxygen partial pressure is set to less than 0.4 Pa, an oxide is less likely to be formed on the surface of the target, the discharge voltage can be prevented from rising, and a challenge of continuation of the discharge can be reduced.

[0067] The above method may further include setting the oxygen partial pressure in the chamber during the evaporation such that the O/Y ratio is less than 1.4.

[0068] This method can further reduce the electric resistance of the film, and a conductive yttrium oxide film can be stably obtained.

[0069] The above method may further include setting the oxygen partial pressure in the chamber such that the electric resistance of the yttrium oxide film is 10,000 Ω or less.

[0070] This method makes it possible to stably obtain a conductive yttrium oxide film having an electric resistance of 10,000 Ω or less by controlling the oxygen partial pressure during film formation and changing the amount of oxygen in the film.

[0071] The above method may further include setting the oxygen partial pressure such that the discharge voltage during film formation is 20 V or less.

[0072] This method can suppress a rise in an increase rate of the discharge voltage due to an increase in the discharge voltage by the oxygen partial pressure, and stably maintain the discharge during film formation.

[0073] The above method may further include that the oxygen partial pressure is 0.17 Pa or more.

[0074] This method can prevent film roughness of the film to be formed from increasing as the oxygen partial pressure decreases.

[0075] The above method may further include introducing argon in addition to oxygen into the chamber.

[0076] This method can reduce the discharge voltage during film formation and stabilize the discharge during film formation.

[0077] The above method may further include applying a pulse voltage as the bias voltage to the substrate.

[0078] Even in a case where the resistance of the coating film formed on the substrate is relatively high, this method can suppress charge-up in which charges are accumulated by the incident ions.

[0079] The present invention can provide a film formation method capable of stably maintaining discharge during film formation in stably forming a conductive yttrium oxide film on a substrate by using an arc ion plating method.

Claims

[Claim 1] A film formation method of forming, by an arc ion plating method, an yttrium oxide film on a substrate that is an object on which a film is to be formed, the method comprising:

- disposing, in a chamber, a target including yttrium and the substrate;
- introducing at least oxygen into the chamber;
- applying a prescribed bias voltage to the substrate;
- evaporating a surface of the target in oxygen to form the yttrium oxide film on the substrate; and
- setting an oxygen partial pressure in the chamber during the evaporation to less than 0.4 Pa such that an O/Y ratio that is a ratio of oxygen to yttrium in the yttrium oxide film on the substrate is 1.5 or less.

[Claim 2] The film formation method of an yttrium oxide film according to claim 1, the method further comprising setting the oxygen partial pressure in the chamber during the evaporation such that the O/Y ratio is less than 1.4.

[Claim 3] The film formation method of an yttrium oxide film according to claim 2, the method further comprising setting the oxygen partial pressure in the chamber such that an electric resistance of the yttrium oxide film is 10,000 Ω or less.

[Claim 4] The film formation method of an yttrium oxide film according to claim 1, the method further comprising setting the oxygen partial pressure such that a discharge voltage during film formation is 20 V or less.

[Claim 5] The film formation method of an yttrium oxide film according to claim 1, the method further comprising that the oxygen partial pressure is 0.17 Pa or more.

[Claim 6] The film formation method of an yttrium oxide film according to any one of claims 1 to 5, the method further comprising introducing argon in addition to oxygen into the chamber.

[Claim 7] The film formation method of an yttrium oxide film according to any one of claims 1 to 5, the method further comprising applying a pulse voltage as the bias voltage to the substrate.