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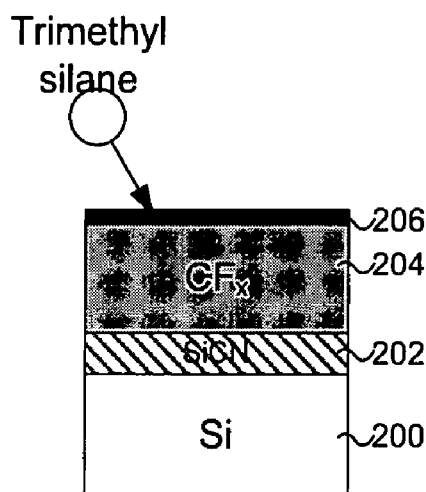
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[Continued on next page]

(54) Title: SEMICONDUCTOR DEVICE AND METHOD FOR MANUFACTURING THE SAME

(57) Abstract: A method for manufacturing a semiconductor device pertaining to the present invention includes the steps of forming a first film containing fluorine added carbon on a semiconductor substrate, forming a second film containing a carbon-carbon bond on the first film, and forming a third film on the second film.

FIG. 4C





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SEMICONDUCTOR DEVICE AND METHOD FOR MANUFACTURING THE SAME

This application claims priority from United States provisional application Serial No. 61/004,539, filed November 27, 2007, entitled "Manufacturing Method for Semiconductor Device", which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0001]

The present invention relates to a semiconductor device and method for manufacturing the same.

BACKGROUND OF THE INVENTION

[0002]

In recent years, the use of a low permittivity material, that is, low-k material as a material for an interlayer insulating film has been attempted to improve operating speeds of semiconductor devices. Especially, a film made of fluorine added carbon (fluorocarbon; CF_x) has been attracting attention as one of the insulating films using the low-k material.

[0003]

By the way, the fluorine (F) atom has a property that water molecules (H₂O) are easily adsorbed. Further, a fluorine atom is oriented on the surface side of the film in the CF_x film. For this reason, the water molecules are

adsorbed on the surface of the film while transferring a substrate etc. if the fluorine atom is exposed on the surface of film and left uncontrolled, the water molecule and fluorine atom react and discharge as a hydrogen fluoride (HF) gas when the substrate is heated at a subsequent process. Because the hydrogen fluoride has a property that corrodes and damages the film, it is necessary to suppress the hydrogen fluoride gas.

[0004]

For this point, a manufacturing method that withdraws the fluorine on the CFx film surface by impinging the plasma generated from the CFx film surface to prevent the hydrogen fluoride gas generation has been proposed. (for example, refer to Japanese Unexamined Patent Application Publication No. 2005-354041).

[0005]

Concretely, first, form a CFx film 104 as shown in figure 1A. Thereafter, withdraw fluorine atoms from the CFx film 104 surface by colliding the plasma generated from a nitrogen gas (N₂) on the CFx film 104 surface as shown in figure 1B while keeping the CFx film 104 from contacting moisture. For this, the CFx film 104 surface changes to a modified area 106 where the fluorine concentration is decreased. And, an insulating film 108 is formed on the modified area 106 as shown in figure 1C.

[0006]

However, according to this manufacturing method, there is not a bonding partner for the carbon (C) atom after the fluorine atom is withdrawn

in an area 105 located right below the modified area 106. Therefore, there is a possibility that the insulating film 108 is peeled from the CFx film 104 starting around the area 105 as shown in figure 1D.

[0007]

The present invention has been made considering the above issues, and an objective is to provide a method for manufacturing a semiconductor device and a semiconductor device that is capable of improving the adhesiveness of the CFx film and a film formed thereon.

SUMMARY OF THE INVENTION

[0008]

In accordance with the first aspect of the present invention, a manufacturing method for a semiconductor device includes the steps of:

forming a first film on a semiconductor substrate, the first film including fluorocarbon;

forming a second film on the first film, the second film including a carbon-carbon bond; and

forming a third film on the second film.

[0009]

According to the first aspect of the present invention, the second film including a carbon-carbon bond is formed on the first film including fluorine added carbon. The second film is a solid film having the carbon-carbon bond capable of preventing the diffusion of the fluorine (F) atom from the first film

surface, thus, the strength does not decrease at the surface of the first film. Further, the second film is a solid film having a carbon-carbon bond, thus, the second film itself has a sufficient strength. Further, the SiC film 206 has a favorable adhesiveness to the CF_x film 204. Therefore, the adhesiveness of the first film and third film can be improved.

[0010]

In the first aspect of the present invention the second film may be formed in an organic silane series gas with bias power applied to the semiconductor substrate.

[0011]

According to the aspect, the second film is formed in an organic silane series gas with bias power applied, the second film may be a film having the carbon-carbon bond.

[0012]

In the first aspect of the present invention, the bias power may be not less than 5W (Watts) and not more than 20W (Watts).

[0013]

According to the aspect, the adhesiveness of the first film and third film may be more favorable.

[0014]

In the first aspect of the present invention the bias power is not less

than 10W (Watts) and not more than 15W (Watts).

[0015]

According to the aspect, the adhesiveness of the first film and third film may be very favorable.

[0016]

In the first aspect of the present invention, a frequency of the bias power may be not less than 100kHz and not more than 20MHz.

[0017]

According to the aspect, the carbon-carbon bond may be formed efficiently.

[0018]

In the first aspect of the present invention, the organic silane series gas may be selected from the group consisting of monomethylsilane ($\text{Si}(\text{CH}_3)\text{H}_3$), dimethylsilane ($\text{Si}(\text{CH}_3)_2\text{H}_2$), trimethylsilane ($(\text{CH}_3)_3\text{SiH}$), and tetramethylsilane ($\text{Si}(\text{CH}_3)_4$).

[0019]

In the first aspect of the present invention, the organic silane series gas may be trimethylsilane ($(\text{CH}_3)_3\text{SiH}$).

[0020]

In the first aspect of the present invention, the second film may have a

thickness of not less than 5nm and not more than 10nm.

[0021]

According to the aspect, the improvement of the adhesiveness of the first film and third film may be realized while suppressing the increase of the permittivity of the second film.

[0022]

In the first aspect of the present invention, the second film may include silicon carbide (SiC).

[0023]

According to the aspect, the adhesiveness of the first film and third film may be improved further.

[0024]

In the first aspect of the present invention, the third film may be an insulating layer including silicon (Si) and carbon (C).

[0025]

According to the aspect, the adhesiveness of the first film and third film may be improved further.

[0026]

In the first aspect of the present invention, the third film may include a

silicon carbonitride (SiCN) or an oxygen added silicon carbide (SiCO).

[0027]

According to the aspect, the adhesiveness of the first film and third film may be improved further.

[0028]

In the first aspect of the present invention, the first film may be maintained so as not to be exposed to moisture during a period after the first film is formed and before the second film is formed.

[0029]

According to the aspect, it is not necessary to remove the moisture attached on the surface of the first film by a recovery process etc.

[0030]

In accordance with the second aspect of the present invention, a manufacturing method for a semiconductor device includes the steps of:

forming a first film on a semiconductor substrate, the first film including fluorocarbon;

forming a second film on the first film; and

forming a third film on the second film;

wherein the second film is formed in an organic silane series gas with a bias power applied to the semiconductor substrate.

[0031]

According to the second aspect of the present invention, the second film is formed using an organic silane series gas with a bias power applied after forming the first film. By applying a bias power using the organic silane series gas, the second film can be a film having a carbon-carbon bond, thereby the adhesiveness of the first film and third film can be improved.

[0032]

In the second aspect of the present invention, the organic silane series gas may be selected from the group consisting of monomethylsilane ($\text{Si}(\text{CH}_3)\text{H}_3$), dimethylsilane ($\text{Si}(\text{CH}_3)_2\text{H}_2$), trimethylsilane ($(\text{CH}_3)_3\text{SiH}$), and tetramethylsilane ($\text{Si}(\text{CH}_3)_4$).

[0033]

In the second aspect of the present invention, the third film may be an insulating layer including silicon (Si) and carbon (C).

[0034]

According to the aspect, the adhesiveness of the first film and third film may be improved further.

[0035]

In the second aspect of the present invention, the third film may include a silicon carbonitride (SiCN) or an oxygen added silicon carbide (SiCO).

[0036]

According to the aspect, the adhesiveness of the first film and third film

may be improved further.

[0037]

In the second aspect of the present invention, the first film may be maintained so as not to be exposed to moisture during a period after the first film is formed and before the second film is formed.

[0038]

According to the aspect, it is not necessary to remove the moisture attached on the surface of the first film by a recovery process etc.

[0039]

In accordance with the third aspect of the present invention, a semiconductor device having a multilayer structure on a semiconductor substrate. The multilayer structure includes:

- a fluorocarbon layer;

- an insulating layer; and

- one layer including a carbon-carbon bond located between the fluorocarbon layer and the insulating layer.

[0040]

According to the third aspect, the layer having a carbon-carbon bond is arranged between the fluorine added carbon layer and insulating layer. The layer having a carbon-carbon bond is a solid film, thus, the layer itself has a sufficient strength. Further, the layer having a carbon-carbon bond has a favorable adhesiveness to the fluorine added carbon layer. For this reason,

the adhesiveness of two films that are formed sandwiching the layer having a carbon-carbon bond, that is, the fluorine added carbon layer and insulating layer, may be improved.

[0041]

In the third aspect of the present invention, the layer may include the carbon-carbon bond includes silicon carbide (SiC).

[0042]

According to the aspect, the adhesiveness of the first film and third film may be improved further.

[0043]

In the third aspect of the present invention, the layer may include the carbon-carbon bond has a thickness of not less than 5nm and not more than 10nm.

[0044]

According to the aspect, the improvement of the adhesiveness of the first film and third film may be realized while suppressing the increase of the permittivity of the second film.

[0045]

In the third aspect of the present invention, the insulating layer may include silicon (Si) and carbon (C).

[0046]

According to the aspect, the adhesiveness of the first film and third film may be improved further.

[0047]

In the third aspect of the present invention, the insulating layer may include a silicon carbonitride (SiCN) or an oxygen added silicon carbide (SiCO).

[0048]

According to the aspect, the adhesiveness of the first film and third film may be improved further.

[0049]

In the third aspect of the present invention, the semiconductor device may further include:

a silicon carbonitride (SiCN) layer between the semiconductor substrate and the fluorocarbon layer.

[0050]

According to the aspect, the SiCN layer is formed between the semiconductor substrate and fluorine added carbon layer. The SiCN layer has an advantage of a favorable adhesiveness to a metal film used as a wire.

BRIEF DESCRIPTION OF THE DRAWINGS

[0051]

Figures 1A to 1D are cross-section diagrams illustrating a manufacturing method for a semiconductor device according to the background art.

Figure 2 is a schematic diagram showing a frame format of a configuration of a portion of a substrate treatment device 1 according to a preferred embodiment.

Figure 3 is a longitudinal cross-section diagram illustrating a configuration of a second insulator forming device.

Figures 4A to 4D are cross section diagrams illustrating a manufacturing process of a semiconductor device pertaining to a preferred embodiment.

DETAILED DESCRIPTION OF INVENTION

[0052]

Preferred embodiments of the present invention will be explained with reference to the drawings. In addition, an explanation of identical elements having substantially the same function and configuration is omitted by using the same reference numbers in the specification and drawings.

[0053]

(Outline configuration of substrate treatment device)

Figure 2 is a plan view illustrating an outline configuration of a portion of a substrate treatment device 1 used to perform a manufacturing method of a semiconductor device pertaining to the present invention.

[0054]

The substrate treatment device 1 has a configuration that a first insulator forming device 10, second insulator forming device 12, third insulator forming device 14, gas supply pipe 21, and gas release pipe 23 are integrally connected to a transfer path 3 where a substrate W is transferred.

[0055]

The transfer path 3 is configured to block inside of the transfer path 3 from air and having a hermetical property. The gas supply pipe 21 is connected to the transfer path 3. And a gas supply apparatus 20 for supplying dry gas is connected to the gas supply pipe 21. The gas supply apparatus 20 can supply dry gas into the transfer path 3 through the gas supply 21. In addition, as a dry gas, inert gas, such as rare gas or nitrogen gas etc., is used. Further, the transfer path 3 is connected to the gas release pipe 23. And a negative pressure generator 22 is connected to the gas release pipe 23. The negative pressure generator 22 can reduce the pressure inside of the transfer path 3 through the gas release pipe 23. Therefore, the inside of the transfer path 3 can be reduced to a predetermined pressure after replacing the atmosphere in the transfer path 3 to a predetermined dry gas. That is, the inside of the transfer path 3 can be maintained to a dry atmosphere not containing moisture after removing the moisture in the transfer path 3.

[0056]

The first insulator forming device 10, second insulator forming device 12 and third insulator forming device 14 are connected to the transfer path 3

through a gate valve 16. The first insulator forming device 10, second insulator forming device 12 and third insulator forming device 14 also have hermetical properties as the transfer path 3, and the atmosphere and pressure can be adjusted inside of each of the devices. The substrate W is selectively transferred to the first insulator forming device 10, second insulator forming device 12 or third insulator forming device 14 through the gate valve 16.

[0057]

From the configuration described above, the substrate W can be selectively transferred to the first insulator forming device 10, second insulator forming device 12 or third insulator forming device 14 and a predetermined treatment can be performed in the first insulator forming device 10, second insulator forming device 12 or third insulator forming device 14 while maintaining the substrate W which is transferred into the transfer path 3, in the dry atmosphere.

[0058]

(Configuration of the insulator forming device)

Next, explained are configurations of the first insulator forming device 10, second insulator forming device 12 and third insulator forming device 14. The first insulator forming device 10, second insulator forming device 12 and third insulator forming device 14 are formed from the same configuration, thus, the second insulator forming device 12 is explained as an example.

[0059]

Figure 3 is a longitudinal cross-section diagram illustrating an outline

of the configuration of the second insulator forming device 12. The second insulator forming device 12 is a CVD (Chemical Vapor Deposition) device for generating a plasma using a radial line slot antenna. A treatment container 5 is a treatment container (vacuum chamber) formed entirely in a cylinder shape. The side wall and bottom section of the treatment container 5 is formed from a conductor, such as aluminum added stainless steel, and a protective layer made of aluminum oxide is formed on the inner wall face.

[0060]

A placing table 51 is formed at substantially the center of the treatment container 5 through an insulating member 51a as a placing section to place the substrate W. This placing table 51 is formed from aluminum nitride (AlN) or aluminum oxide (Al_2O_3). A cooling jacket 51b for distributing a cooling medium is formed inside the placing table 51 and also a heater 57 and power source 58 that form temperature adjustment along with cooling jacket 51b are formed inside. The placing face of the placing table 51 is formed as an electro static chuck. That is, an electrode for the electro static chuck 59 is provided on the placing table 51, and a high voltage power source for the electro static chuck 60 is connected to the electrode for the electro static chuck 59. Further, a high-frequency power source for bias 52 is connected to the placing table 51.

[0061]

The ceiling section of the treatment container 5 is open and a first gas supply section 6, in which a plane shape is formed in a substantial disk shape, is provided to this section through a sealing member (not shown), such as an O-ring so as to face the placing table 51. The first gas supply section 6 is

formed from aluminum oxide. And a gas channel 62 which communicates with one end side of a gas supply hole 61 is formed on a surface facing toward the placing table 51 of the first gas supply section 6. One end side of the first gas supply path 63 is connected to the gas channel 62. Meanwhile, the other end side of the first gas supply path 63 is connected to a gas supply source 64 of argon (Ar) gas or krypton (Kr) gas to generate a plasma. This gas is supplied to the gas channel 62 through the first gas supply path 63, and supplied to a space on the lower side of the first gas supply gas section 6 through the gas supply hole 61.

[0062]

In this example, a unit to supply the gas for generating plasma into the treatment container 5 is formed by the supply source 64, first gas supply path 63, and first gas supply section 6.

[0063]

Further, the treatment container 5 is provided with a second gas supply section 7 with its plane shape formed in a substantial disk shape between the placing table 51 and the first gas supply section 6 so as to divide them. By the second gas supply section 7, inside of the treatment container 5 is divided into a plasma excitation area R1 on the first gas supply section 6 side and plasma diffusion area R2 on the placing table 51 side. This second gas supply section 7 is made of a conductive material, such as an aluminum alloy containing magnesium (Mg), an aluminum added stainless steel, or an aluminum coated with a yttrium oxide (Y_2O_3), and a plurality of gas supply holes 71 are formed on the surface facing the placing table 51. Inside of this gas supply section 7,

formed is a gas channel 72 in a lattice shape communicating with one end side of the gas supply hole 71, and the other end side of the second gas supply path 73 is connected to the gas channel 72. Further, a plurality of openings 74 are formed on the second gas supply section 7 so as to penetrate through the second gas supply section 7. The openings 74 pass plasma or material gas in the plasma to the plasma diffusion area R2, and are formed between the gas channels 72 adjacent to each other.

[0064]

Here, the second gas supply section 7 is connected to a gas supply source 75 of octafluoro-2-pentene (C_5F_8) gas or trimethylsilane(CH_3)₃SiH) that are the material gas, through the second gas supply path 73, and these material gases pass through the gas channel 72 through the second gas supply path 73 in series, and then are supplied to the plasma diffusion area R2 through the gas supply holes 71 uniformly.

[0065]

In this example, a unit for supplying the material gas into the treatment container 5 is formed by the supply source 75, second gas supply path 73, and second gas supply section 7.

[0066]

In figure 3, V1 and V2 indicate valves, and 91 and 92 are the flow rate adjustment units for adjusting the flow rate of the plasma gas and material gas respectively into the treatment container 5.

[0067]

On the upper side of the first gas supply section 6, a cover plate formed from a dielectric body, such as aluminum oxide, is provided through a sealing member (not shown), such as an O-ring, and an antenna 8 is provided on the upper side of the cover plate 53 so as to closely contact with the cover plate 53. The antenna 8 is provided with a flat antenna main body which is in a disk shape and the lower side is open, and a planar antenna member (slot plate) 82 in a disk shape with a plurality of slots are formed and provided so as to block the opening on the lower face side of the antenna main body 81. The antenna main body 81 and planar antenna member 82 are formed from a conductor and configured as a flat hollow disk shaped wave guide. And the lower face of the planar antenna member 82 is connected to the cover plate 53.

[0068]

Further, between the planar antenna member 82 and antenna main body 81, a retardation plate 83 formed from a low-loss dielectric material, such as aluminum oxide or silicon nitride (Si_3N_4) is provided. This retardation plate 83 shortens the wave length of microwave and therefore shortens the guide wavelength in a wave guide. In this example, the Radial Line Slot Antenna 80 is formed by the antenna main body 81, planar antenna member 82 and retardation plate 83.

[0069]

In the antenna 8 described above, the planar antenna member 82 is attached to the treatment container 5 through a sealing member (not shown) so as to closely contact to the cover plate 53. And this antenna 8 is connected

to an external microwave generator through a coaxial waveguide 84 so that a microwave at a frequency of 2.45 GHz or 8.3 GHz is supplied. At this time, a waveguide 84A outside of the coaxial waveguide 84 is connected to the antenna main body 81, and a center conductor 84B is connected to a planar antenna member 82 through an opening formed on the retardation plate 83. In the present invention, the plasma generator is formed from the microwave generator 85, coaxial waveguide 84, and antenna 8.

[0070]

Further, the gas release pipe 54 is connected on the bottom of the treatment container 5, and the gas release pipe 54 is connected to a vacuum pump 56, which is a vacuum exhaust unit, through the pressure adjustment section 55 that forms the pressure adjustment unit, thereby the inside of the treatment container 5 can be vacuumed to a predetermined pressure.

[0071]

Here, the power supply to the microwave generator 85 of the second insulator forming device 12 or the high-frequency power source 52, the opening/closing of the valve V1 and V2 for supplying the plasma gas or material gas, the flow rate adjustment unit 91 and 92, and the pressure adjustment section 55 etc. are controlled based on a program containing steps to form an insulating film under a predetermined condition by a control unit 95 formed from a computer. This program is stored in a memory medium 96, such as, a flexible disk, compact disk, flash memory, or MO (Magneto-Optical Disk), and installed in the control unit 95.

[0072]

(Method for manufacturing a semiconductor device)

Next, a method for manufacturing a semiconductor device according to the embodiment of the present invention is explained using figures 2, 3, and 4A to 4D.

[0073]

First, bring the atmosphere in the transfer path 3 of the substrate treatment device 1 shown in figure 2 to a reduced pressure atmosphere with no moisture. Concretely, replace the atmosphere in the transfer path 3 to a dry gas by the gas supply of the gas supply pipe 21, and reduce to a predetermined pressure by the gas release from the gas release pipe 23.

[0074]

Next, arrange substrate W in the transfer path 3 of the substrate treatment device 1. At this time, the substrate W is in a state where a silicon carbonitride (SiCN) film 202 is formed on a silicon (Si) substrate 200 as a semiconductor substrate as shown in figure 4. In addition, the insulation film may be any film other than SiCN film 202; however, the SiCN film has an advantage of a favorable adhesiveness to a metal film used as a wire. Further, a wire made of copper (Cu), aluminum (Al), tungsten (W) etc. may be formed on the upper side of the SiCN film 202.

[0075]

The substrate W arranged in the transfer path 3 is transferred to the first insulator forming device 10 through the gate valve 16.

[0076]

The substrate W transferred to the first insulator forming device 10 is vacuumed and retained on the placing table 51 in the treatment container 5 as shown in figure 3. At this time, the substrate W is maintained at 350°C by the heat of the heater 57. Next, the release of gas in the treatment container 5 is started by the vacuum pump 56 and the inside of the treatment container is reduced to a pressure of 6 Pascals (45 mTorr). By this depressurization, the inside of the treatment container 5 is maintained to a dry atmosphere that contains no moisture.

[0077]

When the pressure is reduced in the treatment container 5, an argon gas is supplied to the plasma excitation area R1 from the first gas supply path 63. From the radial line slot antenna 80, a microwave of 2.45 GHz is emitted towards the plasma excitation area R1 located right below. By this emission of the microwave, the argon gas is plasmanized in the plasma excitation area R1. At this time, the microwave emitted from the radial line slot antenna 80 is reflected at the second gas supply section 7 and accumulates in the plasma excitation area R1. As a result, a high-density plasma space is formed in the plasma excitation area R1.

[0078]

Meanwhile, a negative high voltage is applied to the electrode for the electro static chuck 59 on the placing table 51 by the high voltage power source for the electro static chuck 60, and the substrate W is vacuum held and

retained on the placing table 51. The plasma generated in the plasma excitation area R1 passes through the opening 74 of the second gas supply section 7 and diffuses into the plasma diffusion area R2. A C_5F_8 gas is supplied to the plasma diffusion area R2 from the second gas supply opening 71 of the second gas supply section 7. The C_5F_8 gas is activated by the plasma diffused from the plasma excitation area R1. By the C_5F_8 gas, a film formed from a fluorine added carbon (fluorocarbon; CFx) made from fluorine (F) atoms and carbon (C) atoms is formed on a SiCN film 202 on the silicon substrate 200 as shown in figure 4B. The CFx film 204 is the first film in the method for manufacturing the semiconductor device pertaining to the present invention. At this time, the fluorine atoms are exposed side by side on a surface of the CFx film 204. Because hydrogen (H) atoms are not contained in the gas used to form the CFx film, the generation of hydrogen fluoride (HF) by the fluorine (F) and hydrogen (H) atoms in the CFx film is prevented, thereby the CFx film formed in this way becomes an insulating film having an extremely superior quality.

[0079]

When the CFx film 204 in a predetermined thickness is formed on the substrate W, the emission of microwave or material gas, and the supply of the plasma gas are stopped, and the substrate W on the placing table 51 is transferred out of the treatment container 5 of the first insulator forming device 10. The substrate W transferred out of the first insulator forming device 10 is transferred to the second insulator forming device 12 through the transfer path 3 shown in figure 2. During this time, the transfer path 3 is maintained to a dry atmosphere to prevent the surface of the CFx film 204 on

the substrate W from exposure to moisture. For this reason, moisture, that is, water molecules (H_2O) do not attach or contact the surface of the CFx film 204 on the substrate W. In addition, it is not necessary to maintain a dry atmosphere in this process. Because moisture attached on the surface can be removed by applying a recovery process, such as, a heat treatment, or plasma surface treatment, therefore even if the moisture is attached on the surface of the CFx film 204 because a dry atmosphere is not maintained. However, applying such a recovery process means an increase in the number of manufacturing process, thus it is favorable to prevent the moisture from attaching by maintaining a dry atmosphere.

[0080]

In the second insulator forming device 12, the inside of the treatment container 5 shown in figure 3 is maintained to a reduced pressure atmosphere of 24 Pa (180 mTorr) in advance by the vacuum pump 56. Thus, the substrate W continues to be maintained in a dry atmosphere even when the substrate W is transferred into the second insulator forming device 12. The substrate W transferred to the second insulator forming device 12 is vacuumed and retained on the placing table 51 in the treatment container 5 as shown in figure 3. At this time substrate W is maintained at 350°C by the heat from the heater 57.

[0081]

Next, an argon gas is supplied to the plasma excitation area R1 from the first gas supply path 63 at a flow rate of 850 sccm. From the radial line slot antenna 80, a microwave of 2.45 GHz is emitted from the plasma

excitation area R1 located right below. By this emission of the microwave, the argon gas is plasmanized in the plasma excitation area R1. At this time, the microwave emitted from the radial line slot antenna 80 reflects at the second gas supply section 7 and cumulates in the plasma excitation area R1. As a result, a high-density plasma space is formed in the plasma excitation area R1.

[0082]

Meanwhile, a power of 10 W (watt) at 400 kHz of frequency is applied to the placing table 51 by the high-frequency power source for bias 52. Thus, the plasma generated in the plasma excitation area R1 passes through the opening of the second gas supply section 7 and diffuses in the plasma excitation area R2. In the plasma diffusion area R2, a trymethyilsilane gas, as a material gas, is supplied from the second gas supply opening 71 of the second gas supply section 7 at a flow rate of 40 sccm. The trymethyilsilane gas is activated by the plasma diffused from the plasma excitation area R1. As shown in figure 4C, a silicon carbide (SiC) film 206, as a second film, is formed on the CF_x film 204 by the plasma of the trymethyilsilane gas. By performing this process for 10 seconds, a SiC film 206 with a film thickness of 7nm can be formed. The SiC film 206 is a film having carbon-carbon bond (hereinafter referred as a "C-C bond film").

[0083]

Here, trymethyilsilane is used as a material gas in this example; however, a C-C bond film can be formed by applying a bias power using an organic series gas other than the trymethyilsilane. For example, monomethyilsilane (Si(CH₃)H₃), dimethyilsilane (Si(CH₃)₂H₂ trymethyilsilane

((CH₃)₃SiH), and tetramethylsilane (Si(CH₃)₄) are included as an organic silane series gas. In addition, the organic silane series gas is a gas that the hydrogen in a silane gas is replaced by an organic matter.

[0084]

Further, the SiC film is formed as a C-C bond film in this example; however, any C-C bond films other than the SiC film may be used. As another C-C bond film, graphite can be considered. However, the SiC film is favorable in the aspect of a low leak current.

[0085]

Further, the film thickness of the SiC film 206 in this example is 7nm; however, it is favorable as long as it is in the range of 5nm or above and 10 nm or less. This is because the permittivity increases when the film thickness of the SiC film 206 exceeds 10nm, and there is a possibility that the contribution can not be made to increase the adhesiveness when the film thickness of the SiC film 206 is smaller than 5nm.

[0086]

Further, the frequency of the bias power by the high-frequency power source for bias 52 is 400 kHz in the example; however, a C-C bond film may be formed efficiently when a frequency is in a range of 100 kHz or above and 20 MHz or below.

[0087]

Further, the bias power is 10W in the example; however, a power in a range of 5W or above and 20W or below may be applied. This point will be

discussed later.

[0088]

When the SiC film 206 is formed in the substrate W, the emission of the microwave or material gas and the supply of the plasma gas are stopped, and the substrate W on the placing table 51 is transferred out of the treatment container 5 of the second insulator forming device 12. The substrate W transferred out of the second insulator forming device 12 is transferred to the third insulator forming device 14 through the transfer path 3 shown in figure 1. At this time, the transfer path 3 may be maintained in a dry atmosphere, or may not be maintained in a dry atmosphere. Further, the substrate W may be transferred out of the substrate treatment device 1 once.

[0089]

Once the substrate W transferred to the third insulator forming device 14, a SiCN film 208 as a third film is formed by a plasma CVD method. At this time, a power by the high-frequency power source for bias 52 is not applied to the placing table 51. As a result, the SiCN film 208 is formed on the SiC film 206 as shown in figure 4D. The film thickness of the SiCN film 208 is 23nm. Instead of the SiCN film 208, an insulating film other than the SiCN film may be formed; however, the insulating film, such as the SiCN film containing carbon (C) and silicon (Si) has an advantage of favorable adhesiveness to the C-C bond film. Especially, the adhesiveness to the SiC film 206 is especially favorable. Other than the SiCN film, oxygen added silicon carbide (SiCO) film can be considered as the insulating film containing carbon (C) and silicon (Si), for example. Further, the film thickness of the

SiCN film 208 is 23nm and the total film thickness of the SiC film 206 and SiCN film 208 is 30nm. This is because there may be a case where the film is planarized by a CMP (Chemical and Mechanical Polishing) method using the SiCN film 208 as a stopper after forming the SiCN film 208. That is, in such a case, it is necessary to keep a certain amount of film thickness to provide for the decrease in film thickness due to the polish of the SiCN film 208 by the CMP process.

[0090]

According to the method for manufacturing a semiconductor device pertaining to the example described above, the SiC film 206, which is a film having C-C bond, is formed on the CF_x film 204. The SiC film 206 is a solid film having a C-C bond capable of preventing the fluorine (F) atom from diffusing from the surface of the CF_x film 204, thus the strength will not decrease at the surface of the CF_x film 204. Further, the SiC film 206 itself has a sufficient strength because the SiC 206 is a solid film having a C-C bond. Therefore, the adhesiveness of the CF_x film 204 and the film (for example SiCN film 208) formed on the SiC film 206 can be improved.

[0091]

Further, according to the method of manufacturing a semiconductor device pertaining to the embodiment, there is a film forming process in which the bias power is applied using an organic silane series gas after forming the CF_x film 204. Because the film having a C-C bond can be formed by applying a bias power using a silane series gas, the adhesiveness of the CF_x film 204 and the film formed on the SiC film 206 can be improved.

[0092]

Further, according to the method for manufacturing a semiconductor device pertaining to the embodiment, until the SiC film 206 is formed after the CFx film 204, the CFx is maintained in a condition where the surface is not exposed to moisture. For this reason, there is no need for removing the moisture attached on the surface of the CFx film from the recovery process etc.

[0093]

Further, according to the method for manufacturing a semiconductor device pertaining to the embodiment, the SiCN film 208 is formed on the SiC film 206. The insulating film including carbon and silicon, such as the SiCN film 208 is excellent in the adhesiveness with the SiC film 206 which is a C-C bond film, thus the adhesiveness of the CFx film 204 and SiCN film 208 can further be improved.

[0094]

Further, if a bias power is applied when forming the SiCN film 208, the permittivity (k value) of the SiCN film 208 increases. However, according to the method for manufacturing a semiconductor device pertaining to the embodiment, the bias power is not applied when forming the SiCN film 208. Therefore, the permittivity (k value) of the SiCN film 208 will not be increased.

[0095]

(Semiconductor Device)

Next, a semiconductor device pertaining to the embodiment of the present invention is explained with reference to figure 4D.

[0096]

As shown in figure 4D, a SiCN film 202 is arranged on a silicon (Si) substrate 200 as a semiconductor substrate. Not only a bulk silicon substrate, a SOI (Silicon on Insulator) substrate, SOQ (Silicon on Quartz) substrate and SOS (Silicon on Sapphire) substrate are included in the silicon substrate 200. Further, an insulating film other than SiCN film may be arranged instead of the SiCN film 202; however, the SiCN film has an advantage in a favorable adhesiveness with a metal film used as a wire. Further, a wire made of copper (Cu), aluminum (Al) or tungsten (W) etc. may be formed on the SiCN film 202.

[0097]

And, a stack structure including the CFx film 204, SiC film 206 and SiCN film 208 is arranged on the SiCN film 202. Especially, the SiC film 206, which is a C-C bond film, is arranged between the CFx film 204 and SiCN film 208 as an insulating film.

[0098]

Concretely, first, the CFx film 204 in a predetermined film thickness is arranged on the SiCN film 202.

[0099]

Onto the CFx film 204, the SiC film 206 as a C-C bond film is arranged. In this embodiment, the SiC film is formed as a C-C bond film; however, a C-C

bond film other than the SiC film may be used. As other C-C bond films, for example, graphite can be considered. However, the SiC film is especially favorable in the standpoint of a low leak current.

[0100]

Further, it is favorable that the film thickness of the SiC film 206 is in a range of 5nm or more and 10nm or less. This is because the permittivity increases when the film thickness of the SiC film 206 is above 10nm, and also there is a possibility of decreasing the effect of preventing the diffusion of fluorine in the CF_x film 204 when the thickness of the SiC film is less than 5nm. In the embodiment, the film thickness of the SiC film 206 is 7nm.

[0101]

Onto the SiC film 206, the SiCN film 208 as an insulating film is arranged. Instead of the SiCN film 208, an insulating film other than the SiCN film may be formed; however, the insulating film including carbon (C) and silicon (Si), such as the SiCN film, has an advantage of superior adhesiveness to the C-C bond film. Especially, the adhesiveness to the SiC film 206 is excellent. Other than the SiCN film, an oxygen added silicon carbide (SiCO) film can be considered as the insulating film containing carbon (C) and silicon (Si).

[0102]

According to the semiconductor device pertaining to the embodiment, the SiC film 206 as a C-C bond film is arranged between the CF_x film 204 and the SiCN film 208 as an insulating film. The SiC film 206 is a solid film

having a C-C bond, thus, the SiC film 206 itself has a sufficient strength. Further, the SiC film has a favorable adhesiveness to the CFx film 204. Therefore, the adhesiveness of two films formed by sandwiching the SiC film 206, that is CFx film 204 and SiCN film 208, can be increased.

[0103]

Further, according to the semiconductor device pertaining to the present invention, the SiCN film 208 is arranged on the SiC film 206. Because the SiCN film 208 is excellent in the adhesiveness with the SiC film 206, the adhesiveness of the CFx film 204 and SiCN film 208 can be further improved.

[0104]

(Adhesiveness Evaluation Result)

Next, explained is an evaluation result for the adhesiveness of the CFx film and SiCN film formed on the C-C bond film on the CFx film. In this evaluation, the relationship between the bias power for forming the C-C bond film and adhesiveness is especially focused.

[0105]

Table 1 shows the result of a tape test after forming the SiC film 206.

[0106]

In the tape test, a wafer in which the CFx film, SiC film, and SiCN film are formed in order on a silicon substrate, is used as a sample. This SiC film is formed while applying the bias power as described in the manufacturing

method of a semiconductor device pertaining to the embodiment of the present invention. And, four types of wafers made by changing the bias power in forming the SiC film were prepared. The bias powers are four types of 5W, 10W, 15W, and 20W as described in the upper column of the Table 1.

[0107]

For each of the wafers prepared, first, grooves in a matrix are applied on the surface of the wafer using a diamond cutter. By this, areas made of a plurality of squares 5 mm on a side are formed on the wafer surface. Next, peel off a piece of adhesive tape, after attaching the adhesive tape on the entire face of the wafer surface.

[0108]

And, by checking to see how much SiCN film is attached on the peeled adhesive tape, the degree in peel of the SiCN film, that is, the adhesiveness of the SiCN film and CF_x film, is evaluated. Concretely, when the number of square area attached on the adhesive tape is one or below, the adhesiveness is determined to be excellent, and when the number of squares is not less than two and not more than five, the adhesiveness is determined to be good.

(Table 1)

Bias Power (W)	5	10	15	20
Adhesiveness	Good	Excellent	Excellent	Good

[0109]

As observed from the Table 1, the adhesiveness is favorable at the bias powers 5W and 20W; however, the adhesiveness is excellent at the bias powers of 10W and 15W.

[0110]

In a case when the bias power is 5W or less, it can be thought that the solid C-C bond film by the effect of bias is not formed. Contrarily, in a case when the bias power is 20W or above, it is thought that the bias damages the SiC film 206 from the application of bias and the adhesiveness is decreased.

[0111]

Based on the evaluation result above, it is confirmed that the favorable adhesiveness can be obtained when the bias power applied to the semiconductor wafer 200 is 5W to 20W when forming the SiC film 206. Further, when the bias power applied to the semiconductor substrate 200 is set to 10W to 15W, further favorable adhesiveness can be obtained.

[0112]

The preferred embodiments of the present invention have been explained with reference to the attached figures. Needless to say, the present invention is not limited to those embodiments. It is obvious that one skilled in the art can easily arrive at various changes and modifications within the scope of the claims and it is also understood that those changes and modifications fall within the technical scope of the present invention.

[0113]

For example, the present invention may be applied to various types of substrate treatment devices other than the substrate treatment device according to the embodiment. For example, the present invention may be applied to a substrate device that has a configuration in which a plurality of insulating film forming devices are not connected to one transfer path.

[0114]

The present invention may be applied to various types of insulating film forming devices other the insulating film forming device pertaining to the embodiments.

CLAIMS

What is claimed is:

1. A manufacturing method for a semiconductor device, the method comprising the steps of:

forming a first film on a semiconductor substrate, the first film including fluorocarbon;

forming a second film on the first film, the second film including a carbon-carbon bond; and

forming a third film on the second film.

2. The manufacturing method of claim 1, wherein the second film is formed in an organic silane series gas with a bias power applied to the semiconductor substrate.

3. The manufacturing method of claim 2, wherein the bias power is not less than 5W (Watts) and not more than 20W (Watts).

4. The manufacturing method of claim 2, wherein the bias power is not less than 10W (Watts) and not more than 15W (Watts).

5. The manufacturing method of claim 2, wherein a frequency of the bias power is not less than 100kHz and not more than 20MHz.

6. The manufacturing method of claim 2, wherein the organic silane

series gas is selected from the group consisting of monomethylsilane ($\text{Si}(\text{CH}_3)\text{H}_3$), dimethylsilane ($\text{Si}(\text{CH}_3)_2\text{H}_2$), trimethylsilane ($(\text{CH}_3)_3\text{SiH}$), and tetramethylsilane ($\text{Si}(\text{CH}_3)_4$).

7. The manufacturing method of claim 2, wherein the organic silane series gas is trimethylsilane ($(\text{CH}_3)_3\text{SiH}$).

8. The manufacturing method of claim 1, wherein the second film has a thickness of not less than 5nm and not more than 10nm.

9. The manufacturing method of claim 1, wherein the second film includes silicon carbide (SiC).

10. The manufacturing method of claim 1, wherein the third film is an insulating layer including silicon (Si) and carbon (C).

11. The manufacturing method of claim 10, wherein the third film includes a silicon carbonitride (SiCN) or an oxygen added silicon carbide (SiCO).

12. The manufacturing method of claim 10, wherein the first film is not exposed to a moisture during a period after the first film is formed and before the second film is formed.

13. A manufacturing method for a semiconductor device, the method comprising the steps of:

forming a first film on a semiconductor substrate, the first film

including fluorocarbon;

forming a second film on the first film; and

forming a third film on the second film;

wherein the second film is formed in an organic silane series gas with a bias power applied to the semiconductor substrate.

14. The manufacturing method of claim 13, wherein the organic silane series gas is selected from the group consisting of monomethylsilane ($\text{Si}(\text{CH}_3)\text{H}_3$), dimethylsilane ($\text{Si}(\text{CH}_3)_2\text{H}_2$), trimethylsilane ($(\text{CH}_3)_3\text{SiH}$), and tetramethylsilane ($\text{Si}(\text{CH}_3)_4$).

15. The manufacturing method of claim 13, wherein the third film is an insulating layer including silicon (Si) and carbon (C).

16. The manufacturing method of claim 15, wherein the third film includes a silicon carbonitride (SiCN) or an oxygen added silicon carbide (SiCO).

17. The manufacturing method of claim 13, wherein the first film is not exposed to moisture during a period after the first film is formed and before the second film is formed.

18. A semiconductor device having a multilayer structure on a semiconductor substrate, the multilayer structure comprising:

a fluorocarbon layer;

an insulating layer; and

one layer including a carbon-carbon bond located between the

fluorocarbon layer and the insulating layer.

19. The semiconductor device of claim 18, wherein the layer including the carbon-carbon bond includes silicon carbide (SiC).

20. The semiconductor device of claim 18, wherein the layer including the carbon-carbon bond has a thickness of not less than 5nm and not more than 10nm.

21. The semiconductor device of claim 18, wherein the insulating layer includes silicon (Si) and carbon (C).

22. The semiconductor device of claim 21, wherein the insulating layer includes a silicon carbonitride (SiCN) or an oxygen added silicon carbide (SiCO).

23. The semiconductor device of claim 18, further comprising:
a silicon carbonitride (SiCN) layer between the semiconductor substrate and the fluorocarbon layer.

FIG. 1A

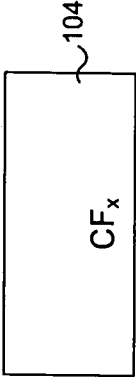


FIG. 1B

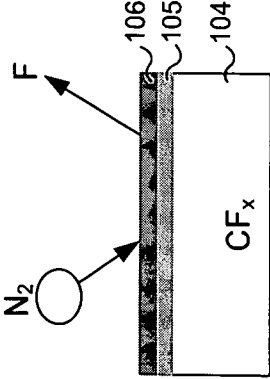


FIG. 1C

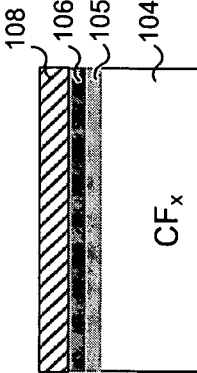


FIG. 1D

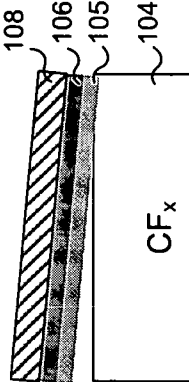


FIG. 2

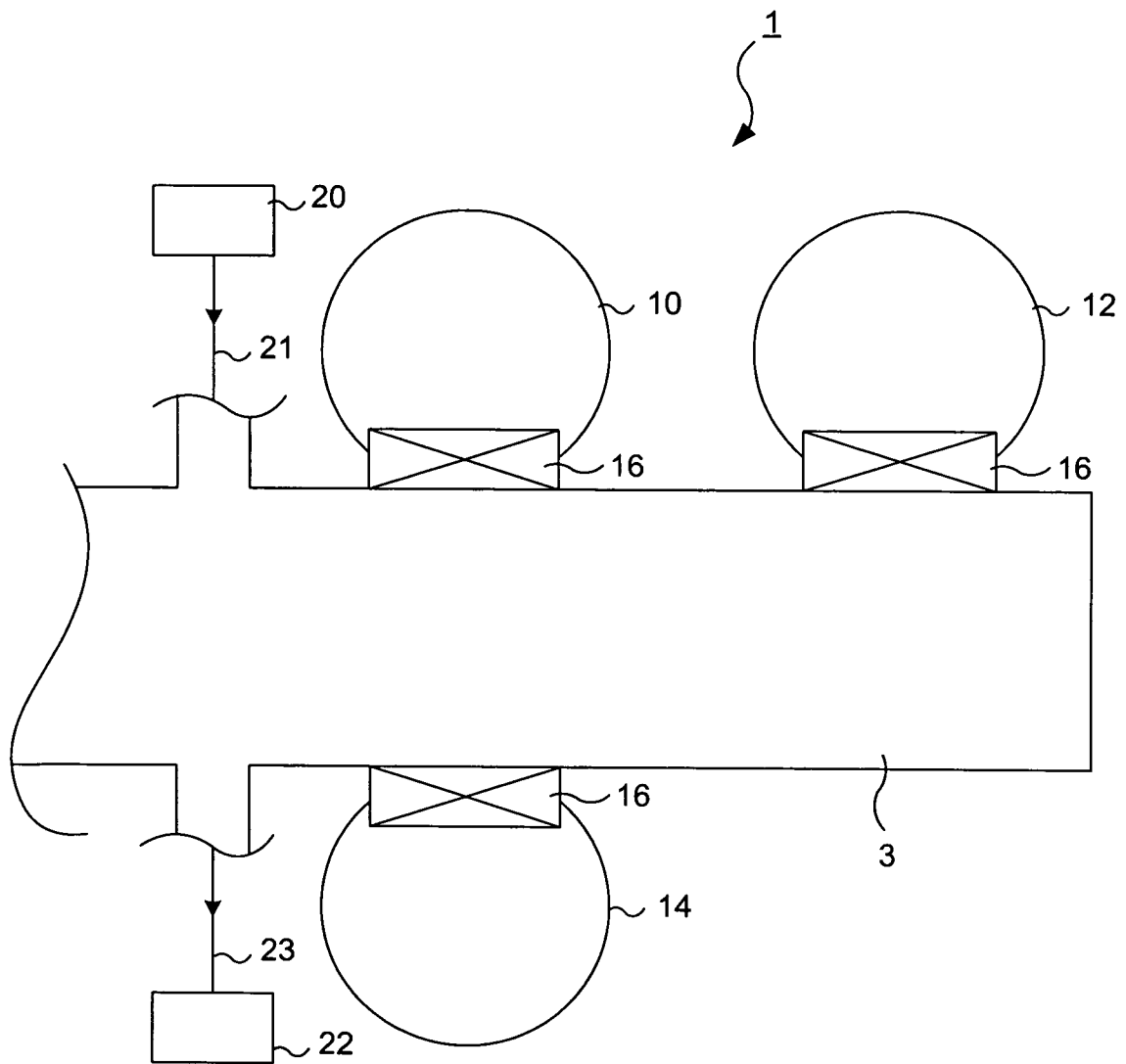


FIG. 3

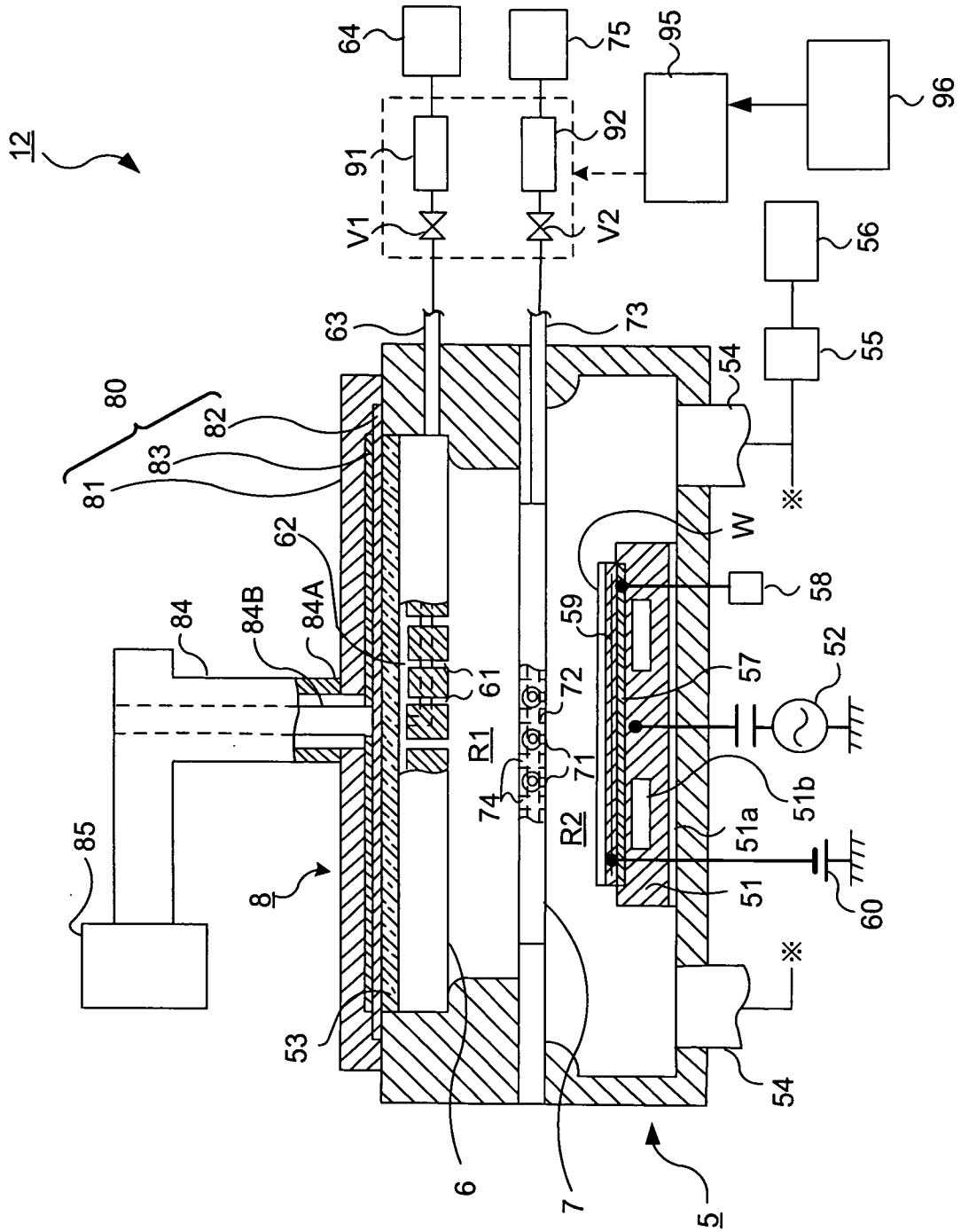


FIG. 4A

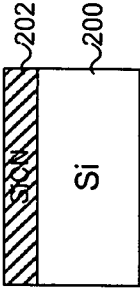


FIG. 4B

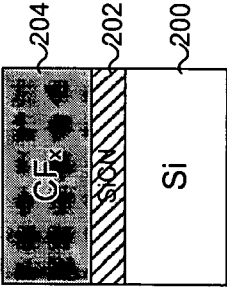


FIG. 4C

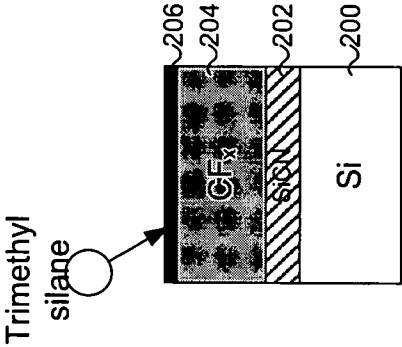


FIG. 4D

