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SUBSTRATE PROCESSING METHOD, METHOD OF MANUFACTURING SEMICONDUCTOR DEVICE, NON- TRANSITORY COMPUTER-READABLE RECORDING MEDIUM AND SUBSTRATE PROCESSING APPARATUS

Abstract

A substrate processing method that enhances film formation on a substrate by dynamically adjusting the distance between the substrate and a gas supply port during processing. The method includes initially positioning the substrate at a first distance to expose at least a portion of its surface to an auxiliary process gas, such as a film-forming auxiliary gas, under conditions that promote uniform gas distribution. The substrate is then moved to a second, shorter distance to undergo sequential exposure to a source gas and, optionally, multiple source gases, to form a film of desired thickness via alternating adsorption and reaction steps. The method further includes stopping gas flow and exhausting residual gases while the substrate remains in the second position, and optionally moving the substrate to a third position for unloading. Associated apparatus, manufacturing methods for semiconductor devices, and computer-readable media configured to implement the process are also disclosed.

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Background/Summary

CROSS-REFERENCE TO RELATED PATENT APPLICATION [0001] This non-provisional U.S. patent application is a continuation of and claims priority to U.S. patent application Ser. No. 17/679,808 filed on Feb. 24, 2022 which claims priority under 35 U.S.C. § 119 of Japanese Patent Application No. 2021-049869, filed on Mar. 24, 2021, in the Japanese Patent Office, the entire contents of which are hereby incorporated by reference.

BACKGROUND

1. Field

[0002] The present disclosure relates to a substrate processing method, a method of manufacturing a semiconductor device, a non-transitory computer-readable recording medium and a substrate processing apparatus.

2. Related Art

[0003] In a method of manufacturing a semiconductor device, a substrate processing apparatus configured to perform a predetermined substrate processing on a substrate may be used. As the substrate processing, for example, a film-forming process in which a plurality of kinds of gases are sequentially supplied may be performed.

[0004] When performing the predetermined substrate processing on the substrate, optimum process conditions such as a process pressure and a supply amount may vary depending on a type of a film formed on the substrate and a type of a gas to be supplied. Therefore, when the substrate processing apparatus described above is used, a uniformity of the film formed on the substrate may deteriorate because a distance between a gas supply port through which the gas is supplied and the substrate is constant.

SUMMARY

[0005] According to the present disclosure, there is provided a technique capable of improving a uniformity of a film formed on a substrate.

[0006] According to one or more embodiments of the present disclosure, there is provided a technique related to a substrate processing method including: (a) setting the substrate at a first position such that a distance between the substrate placed on a substrate support and a gas supply port is a first distance, and processing at least a part of a surface of the substrate by supplying an auxiliary process gas from the auxiliary process gas supplier to the substrate; and (b) moving the substrate to a second position such that a distance between the substrate and the gas supply port is a second distance shorter than the first distance, and processing at least the part of the surface of the

substrate by performing: (b-1) supplying a process gas from the process gas supplier to the substrate; (b-2) stopping a supply of the process gas; and (b-3) exhausting a residual gas from the process chamber while the substrate is maintained at the second position.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. 1 is a diagram schematically illustrating a vertical cross-section of a process furnace of a substrate processing apparatus preferably used in a first embodiment of the present disclosure.

[0008] FIG. 2 is a diagram schematically illustrating a vertical cross-section of the process furnace of the substrate processing apparatus preferably used in the first embodiment of the present disclosure when a substrate is located at a first position.

[0009] FIG. 3 is a block diagram schematically illustrating a configuration of a controller and related components of the substrate processing apparatus preferably used in the first embodiment of the present disclosure.

[0010] FIG. 4 is a diagram schematically illustrating a substrate processing sequence preferably used in the first embodiment of the present disclosure.

[0011] FIG. 5 is a diagram schematically illustrating a modified example of the substrate processing sequence preferably used in the first embodiment of the present disclosure.

[0012] FIG. 6 is a diagram schematically illustrating another modified example of the substrate processing sequence preferably used in the first embodiment of the present disclosure.

[0013] FIG. 7 is a diagram schematically illustrating a vertical cross-section of a substrate processing apparatus preferably used in a second embodiment of the present disclosure.

DETAILED DESCRIPTION

Embodiments

[0014] Hereinafter, one or more embodiments (also simply referred to as “embodiments”) according to the technique of the present disclosure will be described with reference to the drawings. The drawings used in the following descriptions are all schematic. For example, a relationship between dimensions of each component and a ratio of each component shown in the drawing may not always match the actual ones. Further, even between the drawings, the relationship between the dimensions of each component and the ratio of each component may not always match.

First Embodiment

[0015] Hereinafter, a first embodiment according to the technique of the present disclosure will be described.

(1) Configuration of Substrate Processing Apparatus

[0016] As shown in FIG. 1, a substrate processing apparatus **100** includes a process vessel **202**. For example, the process vessel **202** includes a flat and sealed vessel whose horizontal cross-section is circular. For example, the process vessel **202** is made of a metal material such as aluminum (Al) and stainless steel (SUS). A process space **205** in which a wafer W serving as a substrate is processed and a transfer space **206** through which the wafer W passes when the wafer W is transferred into or out of the process space **205** are provided in the process vessel **202**. A process chamber is constituted by an inner space of the process vessel **202**. The process vessel **202** is constituted by an upper vessel **202a** and a lower vessel **202b**. A partition plate **208** is provided between the upper vessel **202a** and the lower vessel **202b**.

[0017] A substrate loading/unloading port **204** is provided adjacent to a gate valve **149** at a side surface of the lower vessel **202b**. The wafer W is transferred between the transfer space **206** and a transfer chamber (not shown) through the substrate loading/unloading port **204**. A plurality of lift pins **207** are provided at a bottom of the lower vessel **202b**.

[0018] A substrate support **210** configured to support the wafer **W** is provided in the process space **205**. The substrate support **210** mainly includes: a substrate mounting table **212** provided with a substrate placing surface **211** on which the wafer **W** is placed; and a heater **213** serving as a heating source provided in the substrate mounting table **212**. A plurality of through-holes **214** through which the lift pins **207** penetrate are provided at positions of the substrate mounting table **212** in a manner corresponding to the lift pins **207**. A heater controller **220** is connected to the heater **213**, and the heater **213** is heated to a desired temperature according to an instruction from a controller **280** described later.

[0019] A shower head **230** serving as a gas dispersion structure is provided in an upper portion (upstream side) of the process space **205**. A lid **231** of the shower head **230** is provided with a gas introduction hole **231a**. The gas introduction hole **231a** is configured to communicate with a gas supply pipe **242** described later.

[0020] The shower head **230** is provided with a dispersion plate **234** serving as a dispersion structure configured to disperse a gas such as a first source gas and a second source gas. An upstream side of the dispersion plate **234** is referred to as a buffer space **232**, and a downstream side of the dispersion plate **234** is referred to as the process space **205**. The dispersion plate **234** is provided with a plurality of through-holes **234a** serving as a gas supply port. The dispersion plate **234** is arranged so as to face the substrate placing surface **211**. For example, the dispersion plate **234** is of a disk shape. The through-holes **234a** are provided over an entire surface of the dispersion plate **234**.

[0021] The upper vessel **202a** includes a flange (not shown). A support block **233** is placed on and fixed to the flange. The support block **233** includes a flange **233a**. The dispersion plate **234** is placed on and fixed to the flange **233a**. In addition, the lid **231** is fixed to an upper surface of the support block **233**.

<Gas Supplier>

[0022] The gas supply pipe **242** is connected to the lid **231** of the shower head **230** so as to communicate with the gas introduction hole **231a** provided at the lid **231**. A first gas supply pipe **243a**, a second gas supply pipe **244a** and a third gas supply pipe **245a** are connected to the gas supply pipe **242**.

<First Gas Supplier>

[0023] A first gas supply source **243b**, a mass flow controller (also simply referred to as an “MFC”) **243c** serving as a flow rate controller (flow rate control structure) and a valve **243d** serving as an opening/closing valve are sequentially provided in this order at the first gas supply pipe **243a** from an upstream side toward a downstream side of the first gas supply pipe **243a** in a gas flow direction.

[0024] An adsorption assist gas serving as a process gas is supplied into the process space **205** through the first gas supply pipe **243a** provided with the MFC **243c** and the valve **243d**, the gas supply pipe **242**, the gas introduction hole **231a**, the buffer space **232** and the through-holes **234a**. The adsorption assist gas assists an adsorption of the first source gas described later onto a surface of the wafer **W**. For example, water vapor (H_2O) may be used as the adsorption assist gas. Since the adsorption assist gas assists a film-forming reaction involving the first source gas and the second source gas supplied in a film-forming step described later, the adsorption assist gas may also be referred to as a “film-forming auxiliary gas”.

[0025] A first gas supplier (which is a first gas supply structure or a first gas supply system) is constituted mainly by the first gas supply pipe **243a**, the MFC **243c** and the valve **243d**. The first gas supplier may also be referred to as a “film-forming auxiliary gas supplier” (which is a film-forming auxiliary gas supply structure or a film-forming auxiliary gas supply system) or an “adsorption assist gas supplier” (which is an adsorption assist gas supply structure or an adsorption assist gas supply system). The first gas supplier may further include the first gas supply source **243b**.

<Second Gas Supplier>

[0026] A second gas supply source **244b**, an MFC **244c** and a valve **244d** are sequentially provided in this order at the second gas supply pipe **244a** from an upstream side toward a downstream side of the second gas supply pipe **244a** in the gas flow direction.

[0027] The first source gas is supplied into the process space **205** through the second gas supply pipe **244a** provided with the MFC **244c** and the valve **244d**, the gas supply pipe **242**, the gas introduction hole **231a**, the buffer space **232** and the through-holes **234a**.

[0028] A second gas supplier (which is a second gas supply structure or a second gas supply system) is constituted mainly by the second gas supply pipe **244a**, the MFC **244c** and the valve **244d**. The second gas supplier may also be referred to as a “first source gas supplier” (which is a first source gas supply structure or a first source gas supply system) or a “source gas supplier” (which is a source gas supply structure or a source gas supply system). The second gas supplier may further include the second gas supply source **244b**.

[0029] For example, a silicon-containing gas may be used as the first source gas. As the silicon-containing gas, for example, dichlorosilane (SiH_2Cl_2 , also referred to as “DCS”) gas or hexachlorodisilane (Si_2Cl_6 , also referred to as “HCDS”) gas is used as the silicon-containing gas.

<Third Gas Supplier>

[0030] A third gas supply source **245b**, an MFC **245c** and a valve **245d** are sequentially provided in this order at the third gas supply pipe **245a** from an upstream side toward a downstream side of the third gas supply pipe **245a** in the gas flow direction.

[0031] The second source gas is supplied into the process space **205** through the third gas supply pipe **245a** provided with the MFC **245c** and the valve **245d**, the gas supply pipe **242**, the gas introduction hole **231a**, the buffer space **232** and the through-holes **234a**.

[0032] A third gas supplier (which is a third gas supply structure or a third gas supply system) is constituted mainly by the third gas supply pipe **245a**, the MFC **245c** and the valve **245d**. The third gas supplier may also be referred to as a “second source gas supplier” (which is a second source gas supply structure or a second source gas supply system) or a “reactive gas supplier” (which is a reactive gas supply structure or a reactive gas supply system). The third gas supplier may further include the third gas supply source **245b**.

[0033] For example, a gas containing one of oxygen (O), nitrogen (N) and carbon (C) and reacting with the first source gas may be used as the second source gas. The present embodiment will be described in detail by way of an example in which an oxygen-containing gas is used as the second source gas. Specifically, ozone (O_3) gas is used as the oxygen-containing gas. The first source gas and the second source gas react with each other to form a silicon oxide film (also simply referred to as an “SiO film) on the wafer W.

[0034] In addition, an inert gas supplier (which is an inert gas supply structure or an inert gas supply system: not shown) through which an inert gas such as nitrogen (N_2) gas is supplied is connected to the gas supply pipe **242**. The inert gas serves as a purge gas for purging a gas remaining in the process vessel **202** or the shower head **230** in a substrate processing described later.

[0035] That is, the shower head **230** functions as the film-forming auxiliary gas supplier (adsorption assist gas supplier) when the adsorption assist gas serving as the process gas is supplied into the process vessel **202**. Further, the shower head **230** functions as the first source gas supplier or the second source gas supplier when the first source gas or the second source gas is supplied into the process vessel **202**. Further, the shower head **230** functions as the inert gas supplier when the inert gas is supplied into the process vessel **202**.

[0036] The substrate mounting table **212** is supported by a shaft **217**. The shaft **217** penetrates a bottom of the process vessel **202**, and is connected to an elevator **218** at an outside of the process vessel **202**.

[0037] The elevator **218** is constituted mainly by: a support shaft (not shown) configured to support the shaft **217**; and an actuator (not shown) configured to elevate/lower or rotate the support shaft. For example, the actuator may include: an elevating structure (not shown) such as a motor configured to elevate and lower the support shaft; and a rotator (not shown) such as a gear configured to rotate the support shaft.

[0038] The wafer W placed on the substrate placing surface **211** of the substrate mounting table **212** may be elevated or lowered by operating the elevator **218** by elevating or lowering the shaft **217** and the substrate mounting table **212**. In addition, a bellows **219** covers a periphery of a lower end of the shaft **217** to maintain the process space **205** airtight.

[0039] When the wafer W is transferred, the substrate mounting table **212** is lowered until the substrate placing surface **211** faces the substrate loading/unloading port **204**, that is, until a transfer position of the wafer W is reached. When the wafer W is processed in an adsorption assist processing step described later, the substrate mounting table **212** is elevated until the wafer W reaches a first position below the process space **205** as shown in FIG. 2. When the wafer W is processed in a film-forming step described later, the substrate mounting table **212** is elevated until the wafer W reaches a second position (which is a processing position) in the process space **205** as shown in FIG. 1. According to the present embodiment, as shown in FIG. 2, the first position refers to a position at which a distance between the surface of the wafer W and the through-holes **234a** of the shower head **230** facing the surface of the wafer W is a first distance “A” shown in FIG. 2. Further, as shown in FIG. 1, the second position refers to a position at which the distance between the surface of the wafer W and the through-holes **234a** of the shower head **230** facing the surface of the wafer W is a second distance “B” shown in FIG. 1 different from the first distance A. In addition, the second position is a position different from the first position in a vertical direction, and, for example, the second distance B is set to be shorter than the first distance A.

[0040] Specifically, the first distance A and the second distance B are distances from a front end (tip) of the through-holes **234a** to the surface of the wafer W. However, in the present embodiment, for convenience of explanation, each of the first distance A and the second distance B is described as a distance from the through-holes **234a** to the surface of the wafer W.

[0041] In addition, for example, the front end of the through-holes **234a** may refer to a front end of a structure constituting the through-holes **234a** with reference to a direction facing the wafer W. For example, a lower end of the dispersion plate **234** may be referred to as the front end of the through-holes **234a**.

<Exhauster>

[0042] Hereinafter, an exhauster (which is an exhaust structure) through which an inner atmosphere of the process vessel **202** is exhausted will be described. An exhaust pipe **262** is connected to the process vessel **202** so as to communicate with the process space **205**. The exhaust pipe **262** is provided at a side surface of the process space **205**. An APC (Automatic Pressure Controller) **266** is provided at the exhaust pipe **262**. The APC **266** serves as a pressure controller capable of controlling an inner pressure of the process space **205** to a predetermined pressure. The APC **266** includes a valve body (not shown) whose opening degree can be adjusted. The APC **266** is configured to adjust a conductance of the exhaust pipe **262** in accordance with an instruction from the controller **280**. A valve **267** is provided at the exhaust pipe **262** on an upstream side of the APC **266**. A pressure monitor **268** configured to measure a pressure of the exhaust pipe **262** is provided at the exhaust pipe **262** on a downstream side of the valve **267**.

[0043] The pressure monitor **268** monitors the pressure of the exhaust pipe **262**. Since the exhaust pipe **262** and the process space **205** communicate with each other, the inner pressure of the process space **205** is indirectly monitored. The pressure monitor **268** is electrically connected to the controller **280**, and is configured to transmit detected pressure data to the controller **280**.

[0044] The exhaust pipe **262**, the pressure monitor **268**, the valve **267** and the APC **266** may be collectively referred to as the exhauster (which is the exhaust structure). In addition, as shown in

FIG. 1, a vacuum pump **269** is provided at the exhaust pipe **262**. The vacuum pump **269** is configured to exhaust the inner atmosphere of the process space **205** through the exhaust pipe **262**. <Controller>

[0045] The substrate processing apparatus **100** includes the controller **280** configured to control operations of components constituting the substrate processing apparatus **100**.

[0046] FIG. 3 is a diagram schematically illustrating a configuration of the controller **280**. The controller **280** serving as a control apparatus (control structure) may be embodied by a computer including a CPU (Central Processing Unit) **280a**, a RAM (Random Access Memory) **280b**, a memory **280c** serving as a storage and an I/O port (input/output port) **280d**. The RAM **280b**, the memory **280c** and the I/O port **280d** may exchange data with the CPU **280a** via an internal bus **280f**.

[0047] For example, an input device **281** such as a keyboard and an external memory **282** are connected to the controller **280**. In addition, a receiver **283** connected to a host apparatus **270** via a network is provided.

[0048] A display device **284** is configured to display information such as data detected by the pressure monitor **268**. While the present embodiment will be described by way of an example in which the input device **281** and the display device **284** are provided separately. However, the present embodiment is not limited thereto. For example, when the input device **281** is constituted by a touch panel serving as a display screen, the input device **281** and the display device **284** may be integrally provided as a single body.

[0049] The memory **280c** is configured by a component such as a flash memory and a hard disk drive (HDD). For example, a process recipe containing information on sequences and conditions of the substrate processing described later, a recipe program serving as a control program configured to control the operation of the substrate processing apparatus **100** to perform the substrate processing, and a table described later may be readably stored in the memory **280c**. The process recipe is obtained by combining steps of the substrate processing described later such that the controller **280** can execute the steps to acquire a predetermined result, and functions as a program. Hereafter, the process recipe and the control program may be collectively or individually referred to as a “program”. In the present specification, the term “program” may refer to the process recipe alone, may refer to the control program alone, or may refer to both of the process recipe and the control program. The RAM **280b** functions as a memory area (work area) where a program or data read by the CPU **280a** is temporarily stored.

[0050] The I/O port **280d** is electrically connected to the components of the substrate processing apparatus **100** described above such as the gate valve **149**, the elevator **218**, the APC **266**, the pressure monitor **268**, the vacuum pump **269**, the MFCs **243c**, **244c** and **245c**, the valves **243d**, **244d**, **245d** and **267** and the heater controller **220**.

[0051] The CPU **280a** is configured to read and execute the control program from the memory **280c** and read the process recipe from the memory **280c** in accordance with an instruction such as an operation command inputted from the input device **281**. The CPU **280a** is configured to be capable of controlling various operations in accordance with the contents of the process recipe such as an opening and closing operation of the gate valve **149**, an elevating and lowering operation of the elevator **218**, a pressure detecting operation of the pressure monitor **268**, an ON/OFF control operation of the vacuum pump **269**, a flow rate adjusting operation of each of the MFCs **243c**, **244c** and **245c**, an opening and closing operation of each of the valves **243d**, **244d**, **245d**, **267** and the APC **266** and a temperature adjusting operation of the heater **213** by the heater controller **220**.

[0052] The controller **280** according to the present embodiment may be embodied by installing the above-described program stored in the external memory **282** into a computer. For example, the external memory **282** may include a magnetic disk such as a hard disk, an optical disk such as a DVD, a magneto-optical disk such as an MO and a semiconductor memory such as a USB memory. A method of providing the program to the computer is not limited to the external memory **282**. For

example, the program may be directly provided to the computer by a communication means such as the Internet and a dedicated line instead of the external memory **282**. In addition, the memory **280c** or the external memory **282** may be embodied by a non-transitory computer readable recording medium. Hereafter, the memory **280c** and the external memory **282** are collectively or individually referred to as a “recording medium”. In the present specification, the term “recording medium” may refer to the memory **280c** alone, may refer to the external memory **282** alone, and may refer to both of the memory **280c** and the external memory **282**.

(2) Substrate Processing

[0053] Hereinafter, as a part of a manufacturing process of a semiconductor device, an example of the substrate processing of forming a film on the wafer W will be described. The substrate processing of forming the film is performed using the substrate processing apparatus **100** described above. In the following description, the operations of the components constituting the substrate processing apparatus **100** are controlled by the controller **280**.

[0054] Hereinafter, the substrate processing according to the present embodiment will be described in detail with reference to FIG. 4.

[0055] The substrate processing according to the present embodiment may include: [0056] (a) setting the wafer W at the first position such that the distance between the first position and the through-holes **234a** of the shower head **230** is the first distance “A”, and causing the adsorption assist gas to be adsorbed onto the wafer W by supplying the adsorption assist gas to the wafer W; and [0057] (b) moving the wafer W to the second position such that the distance between the second position and the through-holes **234a** of the shower head **230** is the second distance “B” different from the first distance “A”, and forming the film of a desired thickness on the wafer W by supplying the source gas.

[0058] Further, a cycle is performed at least once in (b), the cycle including: (b-1) causing a first source contained in the first source gas to be adsorbed onto the wafer W by supplying the first source gas to the wafer W; and (b-2) causing the first source adsorbed on the wafer W to react with a second source contained in the second source gas by supplying the second source gas to the wafer W.

[0059] Further, in the present specification, the term “wafer” may refer to “a wafer itself”, or may refer to “a wafer and a stacked structure (aggregated structure) of a predetermined layer (or layers) or a film (or films) formed on a surface of the wafer”. In the present specification, the term “a surface of a wafer” may refer to “a surface of a wafer itself”, or may refer to “a surface of a predetermined layer or a film formed on a wafer”. That is, the term “wafer” may collectively refer to “a wafer and a predetermined layer (or layers) or a film (or films) formed on a surface of the wafer”. In addition, in the present specification, the term “a surface of a wafer” may refer to “a surface (exposed surface) of a wafer itself” or may refer to “a surface of a predetermined layer or a film formed on a wafer, i.e., a top surface (uppermost surface) of the wafer as a stacked structure”. [0060] Thus, in the present specification, “supplying a predetermined gas to a wafer” may refer to “supplying a predetermined gas directly to a surface (exposed surface) of a wafer itself” or may refer to “supplying a predetermined gas to a layer or a film formed on a wafer, i.e., a top surface of the wafer as a stacked structure”). In addition, in the present specification, “forming a predetermined layer (or a film) on a wafer” may refer to “forming a predetermined layer (or a film) directly on a surface (exposed surface) of a wafer itself” or may refer to “forming a predetermined layer (or a film) on a surface of a predetermined layer or a film formed on a wafer, i.e., a top surface (uppermost surface) of the wafer as a stacked structure”.

[0061] In the present specification, the terms “substrate” and “wafer” may be used as substantially the same meaning. That is, the term “wafer” may be substituted by “substrate” and vice versa.

<Substrate Loading and Placing Step S10>

[0062] In the substrate processing apparatus **100**, the substrate mounting table **212** is lowered to the transfer position of the wafer W such that the lift pins **207** penetrate through the through-holes **214**

of the substrate mounting table **212**. As a result, the lift pins **207** protrude from the surface of the substrate mounting table **212** by a predetermined height. Subsequently, the gate valve **149** is opened, and the wafer W (the wafer to be processed) is transferred (loaded) into the process chamber using a wafer transfer device (not shown). Then, the wafer W is placed onto the lift pins **207**. As a result, the wafer W is supported on the lift pins **207** protruding from the surface of the substrate mounting table **212** in a horizontal orientation.

[0063] After the wafer W is loaded into the process vessel **202**, the wafer transfer device is retracted to the outside of the process vessel **202**, and the gate valve **149** is closed to seal (close) the inside of the process vessel **202** hermetically. Thereafter, by elevating the substrate mounting table **212**, the wafer W is placed on the substrate placing surface **211** of the substrate mounting table **212**.

[0064] When the wafer W is loaded into the process vessel **202** serving as the process chamber in which the wafer W is processed, it is preferable that the N.sub.2 gas serving as the inert gas is supplied into the process vessel **202** by the inert gas supplier while exhausting the process vessel **202** by the exhauster described above. That is, it is preferable that the inert gas is supplied into the process vessel **202** by at least opening a valve of the inert gas supplier while exhausting the process vessel **202** with the vacuum pump **269** in operation and the APC **266** opened. Thereby, it is possible to prevent (or suppress) particles from entering the process vessel **202** and from adhering onto the wafer W. In addition, the vacuum pump **269** may continuously exhaust the process vessel **202** from the substrate loading and placing step **S10** until at least a substrate unloading step **S18** described later is completed.

[0065] When the wafer W is placed on the substrate mounting table **212**, the electric power is supplied to the heater **213** embedded in the substrate mounting table **212** such that a temperature (surface temperature) of the wafer W is adjusted to a predetermined temperature. For example, a temperature of the heater **213** is adjusted by controlling a state of electric conduction to the heater **213** based on temperature information detected by a temperature sensor (not shown).

<Adsorption Assist Processing Step>

[0066] Then, the adsorption assist processing step is performed by performing an adsorption assist gas supply step **S11** and a residual gas removing step **S12** described below.

<Adsorption Assist Gas Supply Step **S11**>

[0067] Subsequently, by elevating the substrate mounting table **212**, the wafer W is moved to the first position at which the distance from the through-holes **234a** is the first distance A as shown in FIG. 2.

[0068] Then, the valve **243d** of the first gas supply pipe **243a** is opened to supply the adsorption assist gas into the first gas supply pipe **243a**. A flow rate of the adsorption assist gas supplied into the first gas supply pipe **243a** is adjusted by the MFC **243c**. The adsorption assist gas whose flow rate is adjusted is then supplied into the process space **205** through the gas supply pipe **242**, the gas introduction hole **231a**, the buffer space **232** and the through-holes **234a**, and is exhausted through the exhaust pipe **262**.

[0069] When the adsorption assist gas is supplied, simultaneously, the N.sub.2 gas serving as the inert gas may be supplied through the gas supply pipe **242**. The N.sub.2 gas whose flow rate is adjusted is then supplied into the process space **205** through the gas supply pipe **242**, the gas introduction hole **231a**, the buffer space **232** and the through-holes **234a**, and is exhausted through the exhaust pipe **262**.

[0070] In the adsorption assist gas supply step **S11**, the adsorption assist gas is supplied into the process space **205** with the wafer W supported by the substrate mounting table **212**. By supplying the adsorption assist gas to the wafer W, the adsorption assist gas is adsorbed onto the surface of the wafer W to form a dangling bond (which is constituted by a component of the adsorption assist gas). In the present embodiment, by the wafer W physically adsorbing the component of the adsorption assist gas (for example, an oxygen component), the dangling bond constituted by the component of the adsorption assist gas is formed on the wafer W.

[0071] The adsorption assist gas assists the adsorption of the first source gas described later onto at least a part of the surface of the wafer W. As a result, in a subsequent first source gas supply step **S13**, the first source gas is easily adsorbed onto the surface of the wafer W.

[0072] In the present embodiment, the first distance A refers to a distance at which an adsorption of the adsorption assist gas is hardly affected by the through-holes **234a** when the adsorption assist gas is adsorbed onto the surface of the wafer W. For example, the “distance at which the adsorption of the adsorption assist gas is hardly affected” may refer to a distance from which the adsorption assist gas can diffuse evenly until it reaches the surface of the wafer W. In other words, the “distance at which the adsorption of the adsorption assist gas is hardly affected” may refer to a distance from which the adsorption assist gas can be uniformly supplied into the surface of the wafer W.

<Residual Gas Removing Step **S12**>

[0073] After a predetermined time has elapsed, the valve **243d** of the first gas supply pipe **243a** is closed to stop a supply of the adsorption assist gas. In the residual gas removing step **S12**, with the valve **267** and the APC **266** of the exhaust pipe **262** open, the vacuum pump **269** vacuum-exhausts the inner atmosphere of the process space **205** to remove a substance (which is a residual gas) remaining in the process space **205** such as the adsorption assist gas which did not react and reaction by-products out of the process space **205** (residual gas removing step). In addition, in the residual gas removing step **S12**, the N.sub.2 gas serving as the inert gas is continuously supplied into the process space **205**. The N.sub.2 gas serves as the purge gas, which improves the efficiency of removing the substance remaining in the process space **205** such as the adsorption assist gas which did not react and the reaction by-products out of the process space **205**. In addition, in the residual gas removing step **S12**, the distance from the through-holes **234a** to the wafer W is maintained at the first distance A.

<Film-Forming Step>

[0074] Then, the film-forming step is performed by performing a cycle including the first source gas supply step **S13**, a residual gas removing step **S14**, a second source gas supply step **S15** and a residual gas removing step **S16** a predetermined number of times (n times).

<First Source Gas Supply Step **S13**>

[0075] Subsequently, by elevating the substrate mounting table **212**, the wafer W is moved to the second position at which the distance from the through-holes **234a** is the second distance B different from the first distance A as shown in FIG. 1. For example, the second distance B is shorter than the first distance A.

[0076] According to the present embodiment, in order to increase a process throughput, the second distance B is set to be shorter than the first distance A. Thereby, it is possible to reduce a space volume of the process space **205**. Thereby, it is possible to purge the residual gas quickly in the residual gas removing step **S14** and the residual gas removing step **S16** described later.

[0077] In the first source gas supply step **S13**, the valve **244d** of the second gas supply pipe **244a** is opened to supply the first source gas into the second gas supply pipe **244a**. A flow rate of the first source gas supplied into the second gas supply pipe **244a** is adjusted by the MFC **244c**. The first source gas whose flow rate is adjusted is then supplied into the process space **205** through the gas supply pipe **242**, the gas introduction hole **231a**, the buffer space **232** and the through-holes **234a**, and is exhausted through the exhaust pipe **262**.

[0078] When the first source gas is supplied, simultaneously, the N.sub.2 gas serving as the inert gas may be supplied through the gas supply pipe **242**. The N.sub.2 gas whose flow rate is adjusted is then supplied into the process space **205** through the gas supply pipe **242**, the gas introduction hole **231a**, the buffer space **232** and the through-holes **234a**, and is exhausted through the exhaust pipe **262**.

[0079] In the first source gas supply step **S13**, the first source gas is supplied into the process space **205** with the wafer W supported by the substrate mounting table **212**. By supplying the first source

gas to the wafer W, the first source gas is adsorbed at a location on the surface of the wafer W at which the adsorption assist gas has been adsorbed. On the other hand, the first source is not adsorbed at a location at which the adsorption assist gas has not been adsorbed. In the first source gas supply step S13, for example, the dangling bond formed on the wafer W and the first source gas contained in the first source gas are bonded together.

<Residual Gas Removing Step S14>

[0080] After a predetermined time has elapsed, the valve 244d of the second gas supply pipe 244a is closed to stop a supply of the first source gas. In the residual gas removing step S14, with the valve 267 and the APC 266 of the exhaust pipe 262 open, the vacuum pump 269 vacuum-exhausts the inner atmosphere of the process space 205 to remove a substance (which is the residual gas) remaining in the process space 205 such as the first source gas which did not react or which contributed to an adsorption of the first source and reaction by-products out of the process space 205 (residual gas removing step). In addition, in the residual gas removing step S14, the N.sub.2 gas serving as the inert gas is continuously supplied into the process space 205. The N.sub.2 gas serves as the purge gas, which improves the efficiency of removing the substance remaining in the process space 205 such as the first source gas which did not react or which contributed to the adsorption of the first source and the reaction by-products out of the process space 205. In addition, in the residual gas removing step S14, the distance from the through-holes 234a to the wafer W is maintained at the second distance B.

<Second Source Gas Supply Step S15>

[0081] After the residual gas is removed from the process space 205 in the residual gas removing step S14, the valve 245d of the third gas supply pipe 245a is opened to supply the second source gas into the third gas supply pipe 245a. A flow rate of the second source gas supplied into the third gas supply pipe 245a is adjusted by the MFC 245c. The second source gas whose flow rate is adjusted is then supplied into the process space 205 through the gas supply pipe 242, the gas introduction hole 231a, the buffer space 232 and the through-holes 234a via the third gas supply pipe 245a, and is exhausted through the exhaust pipe 262.

[0082] When the second source gas is supplied, simultaneously, the N.sub.2 gas serving as the inert gas may be supplied through the gas supply pipe 242. The N.sub.2 gas whose flow rate is adjusted is then supplied into the process space 205 through the gas supply pipe 242, the gas introduction hole 231a, the buffer space 232 and the through-holes 234a, and is exhausted through the exhaust pipe 262.

[0083] In the second source gas supply step S15, the second source gas is supplied into the process space 205 with the wafer W supported by the substrate mounting table 212. By supplying the second source gas to the wafer W, the first source adsorbed onto the wafer W reacts with the second source contained in the second source gas to form a desired film on the wafer W. In the second source gas supply step S15, for example, by supplying the second source on the first source, a film containing the first source and the second source is formed. In addition, in the second source gas supply step S15, the distance from the through-holes 234a to the wafer W is maintained at the second distance B.

<Residual Gas Removing Step S16>

[0084] After a predetermined time has elapsed, the valve 245d of the third gas supply pipe 245a is closed to stop a supply of the second source gas. In the residual gas removing step S16, with the valve 267 and the APC 266 of the exhaust pipe 262 open, the vacuum pump 269 vacuum-exhausts the inner atmosphere of the process space 205 to remove a substance (which is the residual gas) remaining in the process space 205 such as the second source gas which did not react or which contributed to a formation of the film and reaction by-products out of the process space 205 (residual gas removing step). In addition, in the residual gas removing step S16, the distance from the through-holes 234a to the wafer W is maintained at the second distance B.

<Performing Predetermined Number of Times, Step S17>

[0085] By performing the cycle including the first source gas supply step S13, the residual gas removing step S14, the second source gas supply step S15 and the residual gas removing step S16 at least once, that is, the predetermined number of times (n times), the film of a desired thickness is formed on the wafer W.

<Substrate Unloading Step S18>

[0086] After the film-forming step is completed, by lowering the substrate mounting table 212, the wafer W is placed on the lift pins 207 protruding from the surface of the substrate mounting table 212. Thereafter, the gate valve 149 is opened, and the wafer W is transferred (unloaded) out of the process vessel 202 using the wafer transfer device (not shown). Thereafter, when the substrate processing is terminated, the supply of the inert gas through the inert gas supplier into the process vessel 202 is stopped.

[0087] For example, process conditions of the steps described above are as follows:

<Adsorption Assist Gas Supply Step S11>

[0088] Supply Amount: 5 sccm to 1,000 sccm; [0089] Pressure: 133 Pa to 13,332 Pa; and [0090] Process Temperature: 50° C. to 600° C.

<First Source Gas Supply Step S13>

[0091] Supply Amount: 100 sccm to 1,000 sccm; [0092] Pressure: 1,333 Pa to 13,332 Pa; and [0093] Process Temperature: 50° C. to 600° C.

<Second Source Gas Supply Step S15>

[0094] Supply Amount: 100 sccm to 1,000 sccm; [0095] Pressure: 1,333 Pa to 13,332 Pa; and [0096] Process Temperature: 50° C. to 600° C.

[0097] The distance between the gas supply port (that is, the through-holes 234a) and the wafer W in the adsorption assist processing step described above and the distance between the gas supply port and the wafer W in the film-forming step described above may vary depending on optimum process conditions such as a type of the film formed on the wafer W, a type of the gas supplied to the wafer W, a process pressure and a supply amount of the gas. Thereby, it is possible to improve a uniformity of the film formed on the wafer W.

[0098] Subsequently, the reasons why the adsorption assist processing step is performed at the first position and the film-forming step is performed at the second position will be described.

[0099] (a) In order to evenly adsorb the adsorption assist gas on the surface of the wafer W, the adsorption assist processing step is performed at the first position at which the adsorption of the adsorption assist gas is hardly affected by a gas flow through the gas supply port.

[0100] (b) In order to facilitate gas replacement in the process space 205, the film-forming step is performed at the second position at which the space volume of the process space 205 is reduced.

[0101] (c) When it is easy for the adsorption assist gas to be thermally decomposed, the adsorption assist processing step is performed at the first position at which a thermal influence can be reduced.

[0102] Hereinafter, the reasons (a) through (c) will be described in detail. First, the reason (a) will be described. According to the present embodiment, the first position is set to the distance at which the adsorption of the adsorption assist gas onto the surface of the wafer W is hardly affected. For example, the first distance A is set to the distance at which the adsorption assist gas can diffuse evenly until it reaches the surface of the wafer W.

[0103] By setting the first distance A as described above, it is possible to uniformly supply the adsorption assist gas onto the surface of the wafer W in the adsorption assist processing step. Since the adsorption assist gas can be uniformly adsorbed onto the wafer W, it is possible to uniformly form the film in the subsequent film-forming step.

[0104] Subsequently, as a comparative example, a case in which the distance between the gas supply port (the through-holes 234a) and the wafer W in the adsorption assist processing step is shorter than the first distance A will be described. In the comparative example, the distance between the gas supply port and the wafer W in the adsorption assist processing step is set to a

distance at which at least the adsorption assist gas diffuses unevenly.

[0105] In the comparative example, it is conceivable that an arrangement of the through-holes **234a** may affect the wafer W. In the adsorption assist processing step, the adsorption assist gas is supplied toward the wafer W through the through-holes **234a**. However, a partial pressure of the adsorption assist gas passing through the through-holes **234a** is very high. Thus, immediately after the adsorption assist gas is ejected through the through-holes **234a**, a pressure and density of the adsorption assist gas are high.

[0106] In the comparative example, the adsorption assist gas whose density is high is supplied to a portion on the surface of the wafer W immediately below the through-holes **234a**, and the adsorption assist gas whose density is low as compared with that of the adsorption assist gas supplied to the portion immediately below the through-holes **234a** is supplied to another portion on the surface of the wafer W which is a portion other than the portion immediately below the through-holes **234a**. Therefore, the density of the adsorption assist gas adsorbed on the surface of wafer W may be non-uniform on the surface of the wafer W. When the subsequent film-forming step is performed in such a state, the film is formed with the adsorption assist gas non-uniformly adsorbed on the surface of wafer W. Therefore, the film formed on the wafer W also becomes non-uniform likewise.

[0107] On the other hand, when the adsorption assist gas is supplied in a state at which the first distance A is set as in the present embodiment, the adsorption assist gas is uniformly supplied to the surface (processing surface) of the wafer W. As a result, it is possible to uniformly adsorb the adsorption assist gas on the surface of the wafer W. Therefore, it is possible to uniformly form the film even in the film-forming step.

[0108] The reason (b) will be described. By setting the second position such that the second distance B is shorter than the first distance A, it is possible to reduce the space volume of the process space **205**. Thereby, it is possible to quickly purge the inner atmosphere of the process space **205** in the residual gas removing step **S14** and the residual gas removing step **S16** of the film-forming step.

[0109] In particular, when the cycle from the first source gas supply step **S13** to the residual gas removal step **S16** is performed a plurality of times in the film-forming step, it is possible to shorten a process time of the cycle. Thereby, it is possible to greatly shorten a process time of an entire processing (that is, the substrate processing).

[0110] In addition, as a comparative example, the distance between the through-holes **234a** and the wafer W in the film-forming step described above may be set to a distance by which the gas diffuses. However, in the adsorption assist processing step before the film-forming step, since the adsorption assist gas is already uniformly adsorbed onto the wafer W, it is possible to uniformly form the film regardless of positions of the through-holes **234a**. Therefore, the film-forming step can be performed even when the distance between the through-holes **234a** and the wafer W is not sufficient for the gas to diffuse. Therefore, it is preferable to reduce the space volume of the process space **205** in consideration of the process throughput.

[0111] The reason (c) will be described. The present embodiment is more effective when the adsorption assist gas is a gas that is prone to thermal decomposition. As shown in FIG. 2, the heater **213** is provided in the substrate mounting table **212**, and when a distance between the dispersion plate **234** and the substrate mounting table **212** is short, the dispersion plate **234** is affected by the heater **213**. As a result, the temperature of the heater **213** may be elevated to a high temperature.

[0112] When a gas prone to thermal decomposition is supplied in such a situation described above, it is conceivable that the gas is exhausted without being adsorbed onto the wafer W. Therefore, as described in (c) above, when the adsorption assist gas is prone to thermal decomposition, it is preferable that the adsorption assist processing step is performed at the first position at which the thermal influence can be reduced.

(3) Effects According to First Embodiment

[0113] According to the present embodiment, it is possible to obtain one or more among the following effects.

[0114] (a) By improving an adsorptivity of the source gas such as the first source gas on the surface of the wafer W, it is possible to form the film whose uniformity on the surface of the wafer W is improved.

[0115] (b) In particular, by improving the adsorptivity of the source gas on the surface of the wafer W at an initial stage of the film-forming step, it is possible to form a continuous film.

(4) Modified Examples

[0116] Subsequently, modified examples of the substrate processing sequence preferably used in the first embodiment of the present disclosure will be described.

<First Modified Example>

[0117] FIG. 5 is a diagram schematically illustrating a first modified example of the substrate processing sequence shown in FIG. 4. As shown in FIG. 5, in the present modified example, a cycle including the step S11 through the step S17 described above is performed on the wafer W a predetermined number of times (m times), that is, at least once. That is, the cycle of the present modified example, which includes the adsorption assist processing step (S11 and S12) of causing the adsorption assist gas to be adsorbed onto the wafer W and the step S17 of performing the cycle of the first embodiment in which the film-forming step (S13, S14, S15 and S16) are sequentially performed in this order to form the film of the desired thickness on the wafer W, is performed the predetermined number of times (m times), that is, at least once. Thereby, it is possible to form the film of the desired thickness on the wafer W. According to the present modified example, by performing the adsorption assist processing step (S11 and S12) whenever the film-forming step is performed the predetermined number of times (n times), it is possible to assist the adsorption of the first source gas onto at least a portion on the surface of the wafer W. In addition, by improving an adsorptivity of the first source contained in the first source gas, it is possible to form a continuous film of the desired thickness whose uniformity on the surface of the wafer W is improved. In addition, it is also possible to improve the process throughput.

<Second Modified Example>

[0118] FIG. 6 is a diagram schematically illustrating a second modified example of the substrate processing sequence shown in FIG. 4. As shown in FIG. 6, in the present modified example, a cycle including the step S11 through the step S16 described above is performed on the wafer W a predetermined number of times (n times). That is, the cycle of the present modified example, in which the adsorption assist processing step (S11 and S12) of adsorbing the adsorption assist gas on the wafer W and the film-forming step (S13, S14, S15 and S16) of forming the film of the desired thickness on the wafer W are to be sequentially performed, is performed the predetermined number of times (n times), that is, at least once. Thereby, it is possible to form the film of the desired thickness on the wafer W. According to the present modified example, by performing the adsorption assist processing step (S11 and S12) whenever the film-forming step (S13, S14, S15 and S16) is performed, it is possible to assist the adsorption of the first source gas onto at least a portion on the surface of the wafer W. In addition, by improving the adsorptivity of the first source contained in the first source gas, it is also possible to form a continuous film of the desired thickness whose uniformity on the surface of the wafer W is improved.

(5) Other Embodiments

Second Embodiment

[0119] Hereinafter, a second embodiment according to the technique of the present disclosure will be described with reference to FIG. 7. Portions different from those of the first embodiment will be mainly described in detail below, and the description of portions the same as the first embodiment will be omitted.

[0120] A configuration of a substrate processing apparatus of the second embodiment is different from that of the first embodiment. Others are the same as in the first embodiment. Hereinafter, the

configuration of the substrate processing apparatus according to the present embodiment will be described below.

[0121] A substrate processing apparatus **300** includes a process vessel **302** in which the wafer W is processed. For example, the process vessel **302** includes a sealed vessel, and is made of a metal material such as aluminum (Al) and stainless steel (SUS). In an inner portion (that is, a hollow portion) of the process vessel **302**, a process chamber **301** constituting a process space in which the wafer W is processed is provided. A substrate loading/unloading port **301a** and a gate valve **303** configured to open and close the substrate loading/unloading port **301a** are provided on a side wall of the process vessel **302**, and the wafer W can be transferred into or out of the process vessel **302** via the substrate loading/unloading port **301a**.

[0122] The process vessel **302** is divided into a first area, a second area and a third area. In the first area, an adsorption assist gas supplier (which is an adsorption assist gas supply structure or an adsorption assist gas supply system) **304** through which the adsorption assist gas (which is the process gas and the film-forming auxiliary gas) is supplied is provided. The first area may also be referred to as a first process region or an adsorption assist processing region. In the second area, a first source gas supplier (which is a first source gas supply structure or a first source gas supply system) **305** through which the first source gas is supplied is provided. The second area may also be referred to as a second process region or a first source gas supply region. In the third area, a second source gas supplier (which is a second source gas supply structure or a second source gas supply system) **306** through which the second source gas is supplied is provided. The third area may also be referred to as a third process region or a second source gas supply region. The first area serves as an area in which the adsorption assist processing step is performed. The second area and the third area serve as areas in which the film-forming step of forming the film on the wafer W is performed. The second area and the third area may also be referred to as a “film-forming processing area”. In addition, the areas described above communicate with one another.

[0123] A substrate mounting table (which is a part of a substrate support) **310** on which the wafer W is placed and supported is provided in the process vessel **302**. The substrate mounting table **310** can be elevated or lowered. The wafer W is placed on and supported by an upper surface (also referred to as a “substrate placing surface”) of an upper end of the substrate mounting table **310**.

[0124] A slide structure **321** serving as a driver capable of driving the substrate mounting table **310** to reciprocate left and right in the process vessel **302** is connected to a lower end portion of the substrate mounting table **310**. The slide structure **321** is fixed to the bottom of the process vessel **302**. The slide structure **321** is configured to move the substrate mounting table **310** and the wafer W on the substrate placing surface in a horizontal direction between one end and the other end of the process vessel **302**, that is, among the first area, the second area and the third area. For example, the slide structure **321** may be embodied by a combination of components such as a feed screw (ball screw) and driving sources typified by an electric motor M.

[0125] That is, in the process vessel **302**, by reciprocating the substrate mounting table **310** by the slide structure **321**, it is possible to reciprocate the wafer W supported by the substrate mounting table **310** among the first area, the second area and the third area.

[0126] The slide structure **321** performs a reciprocating motion described above by operating each driving source such as the electric motor M. Therefore, regarding relative positional relationships among the wafer W placed on the upper surface of the substrate mounting table **310**, the adsorption assist gas supplier **304**, the first source gas supplier **305** and the second source gas supplier **306**, it is possible to adjust the relative positional relationships by controlling each driving source of the slide structure **321**.

[0127] The adsorption assist gas supplier **304** is provided on a ceiling of the process chamber **301** in the first area. The adsorption assist gas supplier **304** is configured such that the adsorption assist gas is supplied to the wafer W on the substrate mounting table **310** in the first area through the adsorption assist gas supplier **304**. The first gas supplier described above is connected to the

adsorption assist gas supplier **304**.

[0128] The first source gas supplier **305** is provided on the ceiling of the process chamber **301** in the second area. The first source gas supplier **305** is configured such that the first source gas is supplied to the wafer W on the substrate mounting table **310** in the second area through the first source gas supplier **305**. The second gas supplier described above is connected to the first source gas supplier **305**.

[0129] The second source gas supplier **306** is provided on the ceiling of the process chamber **301** in the third area. The second source gas supplier **306** is configured such that the second source gas is supplied to the wafer W on the substrate mounting table **310** in the third area through the second source gas supplier **306**. The third gas supplier described above is connected to the second source gas supplier **306**.

[0130] With the wafer W supported thereon, the substrate mounting table **310** moves such that the wafer W is located at a first position in the process chamber **301** when the adsorption assist processing step is performed in the first area. Then, when the film-forming step is performed in the second area or the third area, the substrate mounting table **310** moves such that the wafer W is located at a second position in the process chamber **301**. In the present embodiment, the first position refers to a position at which a distance between the surface of the wafer W and a gas supply port of the adsorption assist gas supplier **304** facing the surface of the wafer W is a first distance "A" shown in FIG. 7. Further, the second position refers to a position at which the distance between the surface of the wafer W and a gas supply port of the first source gas supplier **305** (or a gas supply port of the second source gas supplier **306**) facing the surface of the wafer W is a second distance "B" shown in FIG. 7 different from the first distance A. In addition, according to the present embodiment, the second position is a position different from the first position both in the vertical direction and the horizontal direction, and, for example, the second distance B is set to be shorter than the first distance A. Even in such a case, the adsorption assist gas is adsorbed onto the surface of the wafer W by supplying the adsorption assist gas to the wafer W, the first source contained in the first source gas is adsorbed onto the surface of the wafer W by supplying the first source gas, and the first source adsorbed on the surface of the wafer W reacts with the second source contained in the second source gas by supplying the second source gas. Thereby, a film of a desired thickness is formed on the wafer W.

[0131] Further, a heater **330** serving as a heating source and configured to heat the wafer W is provided below the substrate placing surface of the substrate mounting table **310**. Unlike the substrate mounting table **310**, the heater **330** is fixed to the process vessel **302** without reciprocating. The heater **330** is provided so as to extend from the first area through the third area. A state of electric conduction to the heater **330** is feedback-controlled based on temperature information detected by a temperature sensor (not shown) provided in the vicinity of the wafer W. As a result, the heater **330** is configured such that the temperature of the wafer W supported by the substrate mounting table **310** is maintained at a predetermined temperature.

[0132] A wafer elevator **350** stands by below the substrate mounting table **310**. The wafer elevator **350** is used when the wafer W is transferred (loaded) into or transferred (unloaded) out of the process vessel **302**.

[0133] An exhaust pipe (not shown) is connected to the process vessel **302** so as to communicate with the process chamber **301**. A vacuum pump (not shown) serving as a vacuum exhaust apparatus is connected to the exhaust pipe via a valve (not shown) serving as an opening/closing valve and an APC (Automatic Pressure Controller) valve (not shown) serving as a pressure regulator (pressure adjusting structure). The vacuum pump is configured to vacuum-exhaust an inner atmosphere of the process vessel **302** such that an inner pressure of the process vessel **302** reaches and is maintained at a predetermined pressure (vacuum degree).

[0134] Even when the substrate processing apparatus **300** described above is used, a substrate processing sequence and process conditions may be substantially the same as those of the first

embodiment described above, and it is possible to obtain substantially the same effects as the first embodiment described above. That is, the distance between the gas supply port and the wafer W in the adsorption assist processing step and the distance between the gas supply port and the wafer W in the film-forming step may vary depending on the optimum process conditions such as the type of the film formed on the wafer W, the type of the gas supplied to the wafer W, the process pressure and the supply amount of the gas. Thereby, it is possible to improve the uniformity of the film formed on the wafer W.

[0135] For example, the second embodiment is described in detail by way of an example in which the distance between the gas supply port of each gas supplier and the wafer W is set to be the first distance A or the second distance B by elevating or lowering the substrate mounting table **310**. However, the second embodiment is not limited thereto. For example, the second embodiment is may also be preferably applied when the distance between the gas supply port of each gas supplier and the wafer W is changed. For example, the distance between the gas supply port of each gas supplier and the wafer W may be changed by setting a height of the wafer W to be constant and differentiating heights of the gas supply port of the adsorption assist gas supplier **304**, the gas supply port of the first source gas supplier **305**, and the gas supply port of the second source gas supplier **306**.

[0136] For example, the embodiments are described in detail by way of an example in which the adsorption assist processing step of supplying the adsorption assist gas is performed before the film-forming step. However, the technique of the present disclosures is not limited thereto. For example, the technique of the present disclosures may also be applied when an adsorption inhibition processing step of supplying an adsorption inhibitory gas inhibiting the adsorption of the first source gas to be supplied later is performed before the film-forming step. The adsorption inhibitory gas inhibits the adsorption of the first source gas to be supplied later on at least a part of the surface of the wafer W. By supplying the adsorption inhibitory gas before the film-forming step as described above, it is possible to inhibit the formation of the film on at least a part of the surface of the wafer W. That is, it is possible to selectively form the film (or to inhibit the formation of the film) at a region on a surface of the wafer W. Since the adsorption inhibitory gas selectively assists (or inhibits) the formation of the film by the source gas in the film-forming step described later, the adsorption inhibitory gas may also be referred to as the “film-forming auxiliary gas”.

[0137] For example, the embodiments are described in detail by way of an example in which the distance between the gas supply port and the wafer W is set to be different by elevating or lowering the substrate mounting table **212** or **310** supporting the wafer W. However, the technique of the present disclosures is not limited thereto. For example, the technique of the present disclosures may also be applied when the distance between the gas supply port and the wafer W is set to be different by moving the gas supply port.

[0138] For example, the embodiments are described in detail by way of an example in which the distance between the gas supply port and the wafer W in the adsorption assist processing step is set to be different from the distance between the gas supply port and the wafer W in the film-forming step (that is, in the first source gas supply step and the second source gas supply step). However, the technique of the present disclosures is not limited thereto. For example, the technique of the present disclosures may also be applied when the distance between the gas supply port and the wafer W in the first source gas supply step is set to be different from the distance between the gas supply port and the wafer W in the second source gas supply step. That is, the adsorption assist gas may be supplied at a position at which the adsorption assist gas is easily adsorbed onto the wafer W in the adsorption assist processing step, the first source gas may be supplied at a position at which the first source gas is easily adsorbed onto the wafer W when the first source gas is supplied in the film-forming step, and the second source gas may be supplied at a position at which the second source gas easily reacts with the first source when the second source gas is supplied in the film-forming step.

[0139] For example, the embodiments are described in detail by way of an example in which the H.sub.2O is used as the adsorption assist gas. However, the technique of the present disclosures is not limited thereto. For example, the technique of the present disclosures may also be applied when a gas such as alcohol is used as the adsorption assist gas. In addition, as the adsorption inhibitory gas, for example, a gas such as ammonia (NH.sub.3) gas and a gas containing amine or alkylaminosilane may be used.

[0140] Further, as the first source gas in the embodiments described above, for example, the silicon-containing gas described above may be used. However, a gas such as trisdimethylaminosilane (Si[N(CH.sub.3).sub.2].sub.3H, abbreviated as 3DMAS) may be used as the first source gas.

[0141] For example, the embodiments are described in detail by way of an example in which the ozone is used as the second source gas. However, another oxygen-containing gas may be used when the SiO film is formed. In addition, the embodiments are described in detail by way of an example in which the SiO film is formed. However, the technique of the present disclosures is not limited thereto. For example, a nitrogen-containing gas may be used when a silicon nitride film (also simply referred to as an “SiN film”) is formed. As the nitrogen-containing gas, for example, a gas such as the ammonia (NH.sub.3) gas may be used.

[0142] For example, the embodiments are described in detail by way of an example in which the SiO film is formed by using the first source gas and the second source gas. However, the technique of the present disclosures is not limited thereto. For example, the technique of the present disclosures may also be applied when three or more source gases are used. In such a case, for example, as one of the source gases, a gas such as a carbon (C)-containing gas or a gas containing impurities such as boron (B) may be used.

[0143] For example, the first embodiment is described in detail by way of an example in which the first gas supplier through the third gas supplier are connected to the gas supply pipe **242** and each gas is supplied into the process space **205** through the gas supply pipe **242**. However, the technique of the present disclosures is not limited thereto. For example, the technique of the present disclosures may also be applied when each of the first gas supplier through the third gas supplier is connected to the lid **231**, and each gas is supplied into the process space **205** through each gas supply pipe.

[0144] For example, recipes used in the substrate processing are preferably prepared individually according to process contents and stored in the memory **280c** via an electric communication line or the external memory **282**. When starting the substrate processing, the CPU **280a** is preferably configured to select an appropriate recipe among the recipes stored in the memory **280c** according to the process contents. Thus, various films of different composition ratios, qualities and thicknesses may be formed in a reproducible manner by using a single substrate processing apparatus. In addition, since the burden on an operator of the substrate processing apparatus may be reduced, various processes may be performed quickly while preventing a malfunction of the substrate processing apparatus.

[0145] The above-described recipe is not limited to creating a new recipe. For example, the recipe may be prepared by changing an existing recipe stored in the substrate processing apparatus in advance. When changing the existing recipe to a new recipe, the new recipe may be installed in the substrate processing apparatus via the electric communication line or the recording medium in which the new recipe is stored. In addition, the existing recipe already stored in the substrate processing apparatus may be directly changed to the new recipe by operating the input device **281** of the substrate processing apparatus.

[0146] A substrate processing sequence and process conditions when the substrate processing apparatus described above is used may be substantially the same as those of the embodiments or the modified examples described above, and it is possible to obtain substantially the same effects as the embodiments or the modified examples described above.

[0147] While the technique of the present disclosure is described in detail by way of the embodiments and the modified examples, the technique of the present disclosure is not limited thereto. For example, the embodiments and the modified examples described above may be appropriately combined.

[0148] According to some embodiments of the present disclosure, it is possible to improve the uniformity of the film formed on the substrate.

Claims

1. A substrate processing method, comprising: (a) setting the substrate at a first position such that a distance between the substrate placed on a substrate support and a gas supply port is a first distance, and processing at least a part of a surface of the substrate by supplying an auxiliary process gas from an auxiliary process gas supplier to the substrate; and (b) moving the substrate to a second position such that a distance between the substrate and the gas supply port is a second distance shorter than the first distance, and processing at least the part of the surface of the substrate by performing: (b-1) supplying a process gas from a process gas supplier to the substrate; (b-2) stopping a supply of the process gas; and (b-3) exhausting a residual gas from a process chamber while the substrate is maintained at the second position.
2. The substrate processing method of claim 1, wherein the process gas comprises a source gas, and the auxiliary process gas comprises a film-forming auxiliary gas.
3. The substrate processing method of claim 2, wherein the source gas comprises a first source gas and a second source gas, and wherein (b) further comprises: (b-4) causing a first source contained in the first source gas to be adsorbed onto at least the part of the surface of the substrate processed in (a) by supplying the first source gas to the substrate; and (b-5) causing the first source adsorbed on at least the part of the surface of the substrate in (b-4) to react with a second source contained in the second source gas by supplying the second source gas to the substrate.
4. The substrate processing method of claim 2, wherein a cycle comprising (b-4) and (b-5) is performed at least once.
5. The substrate processing method of claim 3, wherein (b-3) is performed between performing (b-4) and (b-5) while the substrate is maintained at the second position.
6. The substrate processing method of claim 2, wherein a cycle comprising (a) and (b) is performed at least once, wherein, in (a), the film-forming auxiliary gas is adsorbed onto at least the part of the surface of the substrate, and in (b), a film of a predetermined thickness is formed on at least the part of the surface of the substrate by supplying the source gas thereto.
7. The substrate processing method of claim 2, wherein the film-forming auxiliary gas assists an adsorption of the source gas onto at least the part of the surface of the substrate.
8. The substrate processing method of claim 2, wherein the film-forming auxiliary gas inhibits an adsorption of the source gas onto at least the part of the surface of the substrate.
9. The substrate processing method of claim 2, wherein the film-forming auxiliary gas is prone to thermal decomposition.
10. The substrate processing method of claim 1, wherein the first distance is a distance that the auxiliary process gas is able to diffuse until reaching the substrate.
11. The substrate processing method of claim 1, wherein a volume of a process region becomes smaller in (b) than in (a).
12. The substrate processing method of claim 1, wherein, in (a), the auxiliary process gas is supplied to the substrate through a plurality of diffusion holes serving as the gas supply port, and the first distance is set so as to prevent a density of the auxiliary process gas below the plurality of diffusion holes from becoming an uneven state.
13. The substrate processing method of claim 1, wherein, in (a), the auxiliary process gas is supplied to the substrate through a plurality of diffusion holes serving as the gas supply port, and

wherein the first distance is set such that a density of the auxiliary process gas directly below the plurality of diffusion holes is equal to a density of the auxiliary process gas at locations other than directly below the plurality of diffusion holes.

14. The substrate processing method of claim 1, wherein, in (a), a part of the surface of the substrate is processed with the auxiliary process gas, and wherein, in (b), the part of the surface of the substrate processed with the auxiliary process gas is processed with the process gas.

15. The substrate processing method of claim 1, wherein, in (a), the auxiliary process gas is supplied through a gas supply port of the auxiliary process gas supplier, and wherein, in (b), the process gas is supplied through a gas supply port of the process gas supplier.

16. The substrate processing method of claim 1, wherein, in (a), before the auxiliary process gas is supplied, the substrate support with the substrate placed thereon is elevated from a position at which the substrate is being placed on the substrate support to the first position, and wherein, in (b), before the process gas is supplied, the substrate support with the substrate placed thereon is elevated from the first position to the second position.

17. The substrate processing method of claim 1, further comprising: (c) after (b), moving the substrate to a third position while the supply of the process gas is stopped such that a distance between the substrate and the gas supply port is a third distance greater than the second distance, and unloading the substrate from the process chamber while the substrate is maintained at the third position.

18. A method of manufacturing a semiconductor device comprising the substrate processing method of claim 1.

19. A substrate processing apparatus configured to perform the substrate processing method of claim 1.

20. A non-transitory computer-readable recording medium storing a program that, when executed by one or more processors of a substrate processing apparatus, causes the substrate processing apparatus to perform a method comprising: (a) setting the substrate at a first position such that a distance between the substrate placed on a substrate support and a gas supply port is a first distance, and processing at least a part of a surface of the substrate by supplying an auxiliary process gas from an auxiliary process gas supplier to the substrate; and (b) moving the substrate to a second position such that a distance between the substrate and the gas supply port is a second distance shorter than the first distance, and processing at least the part of the surface of the substrate by performing: (b-1) supplying a process gas from a process gas supplier to the substrate; (b-2) stopping a supply of the process gas; and (b-3) exhausting a residual gas from a process chamber while the substrate is maintained at the second position.
