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DESCRIPTION

VERTICAL HEAT-PROCESSING APPARATUS

Technical Field

The present invention relates to a vertical heat-processing apparatus for heat-processing a plurality of target substrates all together. More specifically, the present invention relates to a vertical heat-processing apparatus having an improved shutter device, which is used for masking the load port of a process chamber after target substrates are unloaded from the process chamber.

In a typical case, a vertical heat-processing apparatus according to the present invention is incorporated for use in a semiconductor processing system. The term "semiconductor process" used herein includes various kinds of processes which are performed to manufacture a semiconductor device or a structure having wiring layers, electrodes, and the like to be connected to a semiconductor device, on a target substrate, such as a semiconductor wafer or a glass substrate, by forming semiconductor layers, insulating layers, and conductive layers in predetermined patterns on the target substrate.

Background Art

In the process of manufacturing semiconductor

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devices, various semiconductor processing apparatuses are used for performing processes, such as film-deposition, oxidation, diffusion, reformation, annealing, and etching, on a target substrate, such as a semiconductor wafer. A vertical heat-processing apparatus for simultaneously heat-processing a number of wafers is known as a processing apparatus of this kind.

In general, a vertical heat-processing apparatus includes an airtight vertical process chamber (reaction tube) configured to accommodate wafers. A load port is formed at the bottom of the process chamber and is selectively opened and closed by a lid, which is moved up and down by an elevator. In the process chamber, the wafers are stacked at intervals in a holder called a wafer boat. The wafer boat with the wafers held thereon is placed on the lid, and loaded and unloaded into and from the process chamber through the load port by the elevator.

A shutter device is disposed below the process chamber to mask the load port after the wafer boat supported on the lid is unloaded through the load port. The shutter device prevents high temperature heat from flowing out of the process chamber through the load port and thermally affecting the area therebelow, when the lid is opened.

FIG. 10 is a perspective view showing the

relationship between a conventional shutter device of this kind and a process chamber (reaction tube). As shown in FIG. 10, the shutter device 110 includes a port cover 118 for covering the load port 104 of a process chamber 103. The port cover 118 is attached to the distal end of a horizontal swing arm 116. The arm 116 can be horizontally swung and moved up and down by a horizontal rotation drive 114 and an elevating mechanism 112 both disposed at the proximal portion.

As shown with a solid line in FIG. 10, when the port cover 118 is not used to close the load port, it is placed at a waiting position laterally shifted from the load port 104. When the port cover 118 is used to close the load port, the arm 116 is horizontally swung by about 60 degrees to move the port cover 118 to a position below the load port 104. Then, the arm 116 is moved up to bring so as for the port cover 118 to come into contact with and close the load port 104.

There is another example of a shutter device, in which a port cover is attached to the distal end of a vertical swing arm (not shown). In this case, the vertical swing arm is vertically swung by a vertical rotation mechanism disposed at the proximal portion. The port cover is moved up by vertically swinging the arm to come into contact with and close the load port.

In the shutter device shown in FIG. 10, the arm 116 is horizontally swung to move the port cover 118.

The port cover 118 has a relatively high weight, which increases the time necessary for controlling the position of the port cover 118 in the opening and closing operations, in the shutter device shown in FIG. 10. For example, in the case of a vertical heat-processing apparatus for wafers of 12 inches, the closing operation takes about 25 seconds for rotation of the arm 116 and about 2 seconds for ascent of the arm 116, which total around 27 seconds. A long operation time of the shutter device brings about a low throughput. Furthermore, the size of the port cover 118 has to be increased with an increase in the diameter of the process chamber, in accordance with the size of wafers. Accordingly, the problem mentioned above will be aggravated for vertical heat-processing apparatuses of the next generation for processing larger wafers.

Disclosure of Invention

An object of the present invention is to provide a vertical heat-processing apparatus that can shorten the time necessary for the opening and closing operations of a shutter device, thereby improving the throughput.

According an aspect of the present invention, there is provided a vertical heat-processing apparatus for heat-processing a plurality of target substrates all together, the apparatus comprising:

an airtight process chamber configured to

accommodate the target substrates, and having a load port at a bottom;

a lid configured to selectively open and close the load port of the process chamber;

a holder configured to hold the target substrates stacked at intervals;

a supply section configured to supply a process gas into the process chamber;

an exhaust section configured to exhaust the process chamber,

a heater configured to heat an atmosphere in the process chamber;

an elevator configured to move the lid up and down, along with the holder placed thereon, which holds the target substrates; and

a shutter device configured to mask the load port after the target substrates are unloaded from the process chamber through the load port,

the shutter device comprising

a port cover configured to selectively closing the load port of the process chamber, and

an actuator including an extensible/contractible arm that supports and moves the port cover, the actuator being configured to linearly move the port cover by the extensible/contractible arm between a closing position to close the load port and a waiting position laterally shifted from the closing position.

The vertical heat-processing apparatus may be arranged in a form wherein the extensible/contractible arm comprises a proximal portion and a plurality of arm elements supported by the proximal portion and supporting the port cover, and the plurality of arm elements comprise a first arm element reciprocable relative to the proximal portion and a second arm element reciprocable relative to the first arm element.

The vertical heat-processing apparatus may be arranged in a form wherein the shutter device further comprises a casing configured to accommodate the port cover and the extensible/contractible arm, such that the extensible/contractible arm is tucked away in the casing at the waiting position.

The vertical heat-processing apparatus may be arranged in a form wherein the shutter device further comprises a controller that controls an operation of the extensible/contractible arm, and the controller is arranged to perform reciprocation of the second arm element relative to the first arm element only when the first arm element is in the casing.

The vertical heat-processing apparatus may be arranged in a form wherein the casing comprises a first opening formed in a first side of the casing facing the closing position, and a second opening formed in a second side of the casing different from the first side, and the apparatus further comprises a mechanism

configured to form a gas flow flowing in through the first opening and flowing out through the second opening.

Brief Description of Drawings

FIG. 1 is a structural view schematically showing a vertical heat-processing apparatus according to an embodiment of the present invention;

FIG. 2 is a plan view schematically showing the inner structure of a shutter device used in the apparatus shown in FIG. 1;

FIG. 3 is a front view schematically showing the inner structure of the shutter device shown in FIG. 2;

FIG. 4 is a side view schematically showing the inner structure of the shutter device shown in FIG. 2;

FIGS. 5A and 5B are a plan view and a side view, respectively, of the shutter device shown in FIG. 2, in a state (tuck-away state) where first and second arm elements are contracted;

FIGS. 5C and 5D are a plan view and a side view, respectively, of the shutter device shown in FIG. 2, in a state where only the second arm element is extended;

FIGS. 6A and 6B are a plan view and a side view, respectively, of the shutter device shown in FIG. 2, in a state (extension state) where the first and second arm elements are extended;

FIGS. 6C and 6D are a plan view and a side view, respectively, of the shutter device shown in FIG. 2, in

a state where only the first arm element is contracted;

FIG. 7 is a perspective view schematically showing a ventilation structure for the working area of the apparatus shown in FIG. 1;

FIG. 8 is a sectional view schematically showing the ventilation structure for the working area of the apparatus shown in FIG. 1;

FIG. 9 is a side view schematically showing a shutter device according to another embodiment of the present invention; and

FIG. 10 is a perspective view showing the relationship between a conventional shutter device and a process chamber in a vertical heat-processing apparatus.

Best Mode for Carrying Out the Invention

Embodiments of the present invention will be described hereinafter with reference to the accompanying drawings. In the following description, the constituent elements having substantially the same function and arrangement are denoted by the same reference numerals, and a repetitive description will be made only when necessary.

FIG. 1 is a structural view schematically showing a vertical heat-processing apparatus according to an embodiment of the present invention. As shown in FIG. 1, the shell of the vertical heat-processing apparatus 1 is formed of a housing 2. A vertical

heat-processing furnace 3 is disposed at an upper position in the housing 2, and is used for performing a predetermined process, such as an oxidation process, on a plurality of target substrates, such as semiconductor wafers W. The heat-processing furnace 3 includes a vertically long process chamber, such as a quartz reaction tube 5, which has an opening at the bottom as a load port 4.

The load port 4 of the reaction tube (process chamber) 5 is selectively opened and closed by a lid 6, which is movable up and down. The lid 6 is arranged to come into contact with the lip of the load port 4 to airtightly close the load port 4. A wafer boat 9 is disposed on the lid 6, for holding a plurality of wafers W in a state where they are stacked at intervals. A rotation mechanism 11a is disposed below the lid 6, for rotating the wafer boat 9.

A heater 7 is disposed around the reaction tube 5. The heater 7 is controlled to heat the atmosphere in the reaction tube (process chamber) 5 to a predetermined temperature, such as 300 to 1,200℃. The reaction tube is connected to a gas supply section GS including a plurality of gas feed lines for supplying process gases and an inactive purge gas into the reaction tube 5. The reaction tube 5 is also connected to an exhaust section ES for exhausting the interior of the reaction tube 5.

When wafers W are processed in the reaction tube 5, they are held in a horizontal state and stacked at intervals by the wafer boat 9. The wafer boat 9 includes a quartz boat body 9a configured to hold a number of, e.g., 25 to 150, wafers W having a large diameter of, e.g., 300 mm. The boat body 9a is provided with a leg portion 9b at the bottom, which is formed integratedly with the boat body 9a. The leg portion 9b is connected to the rotational shaft of a rotation mechanism 11a attached to the lid 6 to rotate the wafers W in the angular direction. A heating mechanism or thermally insulating cylinder (not shown) is further disposed on the lid 6.

A base plate 8 made of, e.g., stainless steel is horizontally arranged in the housing 2 to install the reaction tube 5 and heater 7 constituting the heat-processing furnace 3. The base plate 8 is provided with an opening (not shown) formed therein, into which the reaction tube 5 is inserted from below. The reaction tube 5 has an outward flange at the bottom, which is held by the base plate 8 through a flange holder. The reaction tube 5 is detachable downward from the base plate 8, for cleaning and so forth.

The housing 2 contains a working area (loading area) 10 below the heat-processing furnace 3, for transferring wafers W to and from the wafer boat 9.

An elevating mechanism (elevator) 11 is disposed in the working area 10 to move the lid 6 up and down (only the arm of the elevator 11 that supports the lid 6 is shown in FIG. 1). The wafer boat 9 is moved between the working area 10 and reaction tube 5 by the elevator 11, while it is supported on the lid 6. In other words, the wafer boat 9 is loaded and unloaded to and from the reaction tube 5 by the elevator 11.

A table 13 is disposed on the front side of the housing 2, for placing a plurality of carriers (or cassettes) 12 each configured to store wafers W. Each of the carriers 12 can store a plurality of, e.g., about 25, wafers. Each carrier 12 is formed as an airtight transfer container, which has a lid (not shown) on the front side.

A table-port structure 13a is disposed inside the front of the working area 10, for placing a carrier 12 thereon and bringing the entrance of the carrier 12 into contact with the working area 10 side. A port is formed in the partition between the working area 10 and table-port structure 13a, and configured to be opened/closed by a door 14. The door 14 is provided with a mechanism for attaching and detaching the lid of the carrier 12. The door 14 is also provided with replacing means (not shown) disposed near it, for replacing the atmosphere in the carrier 12 placed on the table-port structure 13a with an inactive gas.

A transfer device 15 is disposed in the working area 10, for transferring wafers W between the carrier 12 and wafer boat 9. Storage shelves 16 are disposed outside and above the front of the working area 10, for storing two carriers at two positions vertically arrayed. A transfer device (not shown) is also disposed there, for transferring carriers between the table 13 and storage shelves 16.

A shutter device 17 is disposed at the top inside the working area 10, for masking the load port 4 when the lid 6 is detached from the load port 4 of the reaction tube 5. The shutter device 17 is used for preventing high temperature heat from flowing out of the reaction tube 5 through the load port 4 and thermally affecting the area therebelow. For this purpose, the shutter device 17 has a port cover 18 for selectively opening and closing the load port 4.

The port cover 18 is supported at the distal end of an extensible/contractible arm 19. The proximal portion of the arm 19 is attached to the housing 2 through a support structure 20. The port cover 18 is linearly moved by extension/contraction of the arm 19 between a closing position PB for closing the load port 4 and a waiting position PA laterally sifted therefrom.

At the waiting position PA, all of the port cover 18, the arm 19, and the driving parts of the arm 19 (which will be described later in detail) are encased

in a casing 21 fixed to the housing 2. The interior of the casing 21 is ventilated within the interior of working area 10, as described later. FIGS. 7 and 8 are a perspective view and a sectional view, respectively, schematically showing a ventilation structure for the working area 10 and casing 21.

A front opening 52 having a size that allows the port cover 18 and arm 19 to pass therethrough is formed in the side of the casing 21 facing the closing position PB. A ventilation opening 54 is formed in another side (the left side in FIGS. 7 and 8) of the casing 21. The other portions of the casing 21 are closed to essentially prevent a gas flow from being formed, although it is not airtight. A ventilation opening 56 is also formed in a side (the left side in FIGS. 7 and 8) of the working area 10 outside the casing 21.

The openings 54 and 56 are connected to a ventilation passage 62 including a duct 58 extending along a side of the housing 2 of the apparatus 1. The ventilation passage 62 extends at the bottom of the housing 2 and is connected to a filter unit 68 through a heat exchanger 64 and a fan (gas suction member) 66. The filter unit 68 is disposed to face the working area 10 on a side of the housing 2 opposite the duct 58.

Accordingly, the working area 10 is supplied with a clean gas from the filter unit 68, utilizing the air

stream produced by the fan 66. The clean gas forms a gas flow FG in the working area 10 and casing 21, and flows through the openings 54 and 56, formed on the opposite side, into the exhaust duct 58. The clean gas thus used and has entered the duct 58 is returned to the filter unit 68 by the air stream produced by the fan 66, so that it is recycled after being cleaned by the filter unit 68.

Particularly, part of the clean air flows into the casing 21 through the front opening 52 of the casing 21, and then flows out into the exhaust duct 58 through the side opening 54. The gas flow FG thus formed from the outside into the inside of the casing 21 through the front opening 52 of the casing 21 prevents dust (fine particles) generated in the casing 21 from flowing out into the working area 10 (particularly, the dust is generated at portions where the arm elements of the extensible/contractible arm 19 come into contact with each other in sliding). As a consequence, it is possible to prevent wafers W handled in the working area 10 from being contaminated with dust generated in the shutter device 17, when it operates in a manner described later.

FIGS. 2 to 4 are a plan view, front view, and side view, respectively, schematically showing the inner structure of the shutter device 17. As shown in FIGS. 2 to 4, the support structure 20 supporting the

extensible/contractible arm 19 includes front supports 20a and a rear support 20b. The pair of right and left front supports 20a are fixed to the bottom of the base plate 8. The rear support 20b is fixed to a frame 2a of the housing 2.

The arm 19 has a proximal arm element 22, first arm element (intermediate arm element) 24, and second arm element (distal arm element) 26. The first arm element 24 is disposed on the proximal arm element 22 through a linear guide 23, so that it is slidable in the longitudinal direction. The second arm element 26 is disposed on the first arm element 24 through a linear guide 25, so that it is slidable in the longitudinal direction.

The first and second arm elements 24 and 26 are moved back and forth by first and second cylinders 27 and 28, respectively. Each of the first and second cylinders 27 and 28 is formed of so called a rod-less cylinder. The rod-less cylinder includes a cylinder tube 27a or 28a in which a piston with a magnet is slidably inserted. A movable ring 27b or 28b with a magnet is slidably fitted around the cylinder tube 27a or 28a, so that it can move along with the piston.

The first cylinder 27 is attached to the proximal arm element 22, and the movable ring 27b is connected to the first arm element 24. The second cylinder 28 is

attached to the first arm element 24, and the movable ring 28b is connected to the second arm element 26. The bottom of the proximal arm element 22 is attached to the bottom plate 30 defining the bottom of the casing 21. The bottom plate 30 can be selectively inclined along with the extensible/contractible arm 19.

Specifically, the extensible/contractible arm 19 is supported by and rotatable about an axis portion disposed on the proximal side, as shown in FIG. 4. With this arrangement, the extensible/contractible arm 19 can be switched between a horizontal set state where it moves between the closing position PB and waiting position PA, and a maintenance state PC where it is inclined for an operator to access it. More specifically, the proximal portion of the proximal arm element 22 is supported to be vertically rotatable, by a shaft 31 at the lower end of the rear support 20b. The bottom plate 30 is connected to the supports 20a through links or stays 32. The stays 32 hold the arm 19 through the bottom plate 30, in the maintenance state PC where the arm 19 is inclined downward.

The bottom plate 30 is fixed to the front supports 20a by screws (not shown) and held in a horizontal state. When the screws are unfastened, the bottom plate 30 is separated from the front supports 20a and inclined downward. In this embodiment, the arm 19 and bottom plate 30 are manually moved up and down by an

operator (i.e., the shutter device 17 is moved between the normal horizontal set state and maintenance state).

The port cover 18 is attached to the upper side of the distal end of the second arm element 26. The port cover 18 is made of, e.g., stainless steel, and includes a water-cooling structure (cooling structure), in which a cooling-water passage 33 of, e.g., a helical shape is formed. Metal conduit tubes 34 extend from a side of the second arm element 26 and communicate with the cooling-water passage 33 in the port cover 18. Heat-resistant and flexible conduit tubes 35 made of, e.g., teflon (TM) are connected to the conduit tubes 34, and are led toward the casing 21.

A distal end cover 36 is disposed next to the distal ends of the conduit tubes 34 to protect the conduit tubes 35 from heat emitted from the load port 4. An intermediate cover 37 having a U-shape in the cross-section is disposed on one side of the first arm element 24 to allow the distal end cover 36 to move. A tube bearing 38 is arranged to guide a flexible tube for supplying a pressurized gas to the second cylinder 28, so that it is not slack.

When the shutter device 17 is opened/closed, the extensible/contractible arm 19 is controlled in, e.g., sequential control by a controller. The controller controls reciprocation of the second arm element 26 relative to the first arm element 24, such that it is

performed only when the first arm element 24 is in the casing 21. This arrangement prevents dust generated by slide of the arm 19 from flowing out into the working area 10.

More specifically, when the port cover 18 is moved (for the closing operation) from the waiting position PA (in the casing 21) to the closing position PB, the second arm element 26 is first moved forward, as shown in FIGS. 5A, 5B, 5C, and 5D, and then the first arm element 24 is moved forward, as shown in FIGS. 6A and 6B. On the other hand, when the port cover 18 is moved (for the opening operation) from the closing position PB to the waiting position PA (in the casing 21), the first arm element 24 is first moved backward, as shown in FIGS. 6A, 6B, 6C, and 6D, and then the second arm element 26 is moved backward, as shown in FIGS. 5A and 5B.

Since the arm 19 is slid in the casing 21 for extension and contraction, dust generated by the slide is exhausted by a gas flow formed in the casing 21. As a consequence, the dust is prevented from flowing out into the working area 10.

Sensors are used to detect positions of the first arm element 24 and second arm element 26 of the arm 19 in extension and contraction (i.e., stroke ends), in the casing 21 where they are hardly affected by heat from the load port 4. There should be as few sensors

as possible. For this purpose, in this example, three sensors, such as limit switches 38a, 38b, and 38c, are disposed on the proximal arm element 22, at predetermined intervals in the longitudinal direction.

A kicker 39 is slidably disposed on the proximal arm element 22 by a guide rail 40, to sequentially turn on/off the limit switches 38a to 38c. The kicker 39 is provided with hook portions 39a and 39b disposed separately one on either of the front and rear sides. The first and second arm elements 24 and 26 are provided with operation rods 41a and 41b extending from their sides to engage with the hook portions 39a and 39b, thereby operating the kicker 39.

For example, when the port cover 18 is moved for the closing operation from the waiting position PA (in the casing 21) to the closing position PB, the limit switches 38a to 38c operate as follows. First, from the contracted state of the arm 19 shown in FIGS. 5A and 5B, the second arm element 26 is moved forward relative to the first arm element 24. In this movement, as shown in FIGS. 5C and 5D, the operation rod 41b of the second arm element 26 engages with the hook portion 39a on the front side of the kicker 39 and transfers the kicker 39 to a position corresponding to the intermediate limit switch 38b. As a consequence, the limit switch 38b is turned on, and thereby detects that the second arm element 26 has been extended.

Then, the first arm element 24 is moved forward relative to the proximal arm element 22. In this movement, as shown in FIGS. 6A and 6B, the operation rod 41b of the second arm element 26 engages with the hook portion 39a on the front side of the kicker 39 and transfers the kicker 39 to a position corresponding to the front limit switch 38c. As a consequence, the limit switch 38c is turned on, and thereby detects that the first arm element 24 has been extended, i.e., the port cover 18 has reached the closing position PB.

On the other hand, when the port cover 18 is moved for the opening operation from the closing position PB to the waiting position PA (in the casing 21), the limit switches 38a to 38c operate as follows. First, from the extended state of the arm 19 shown in FIGS. 6A and 6B, the first arm element 24 is moved backward relative to the proximal arm element 22. In this movement, as shown in FIGS. 6C and 6D, the operation rod 41a of the first arm element 24 engages with the hook portion 39b on the rear side of the kicker 39 and transfers the kicker 39 to a position corresponding to the intermediate limit switch 38b. As a consequence, the limit switch 38b is turned on, and thereby detects that the first arm element 24 has been contracted.

Then, the second arm element 26 is moved backward relative to the first arm element 24. In this movement, as shown in FIGS. 5A and 5B, the operation

rod 41b of the second arm element 26 engages with the hook portion 39b on the rear side of the kicker 39 and transfers the kicker 39 to a position corresponding to the rear limit switch 38a. As a consequence, the limit switch 38a is turned on, and thereby detects that the second arm element 26 has been contracted, i.e., the port cover 18 has reached the waiting position PA.

Next, an explanation will be given an operation of the shutter device 17 having the structure described above. In the regular operation, the shutter device 17 is in a state where it does not interfere with loading and unloading of the wafer boat into and out of the heat-processing furnace 3. Specifically, the extensible/contractible arm 19 is contracted to place the port cover 18 in the waiting position PA, and thus it is tucked away along with the port cover 18 in the casing 21.

When the lid 6 is moved down and opened by the elevator (elevating mechanism) 11, i.e., the wafer boat 9 is unloaded into the working area 10 after heat-processing, the arm 19 of the shutter device 17 is extended to move the port cover 18 to the closing position PB, thereby covering the load port 4 with the port cover 18. As a consequence, high temperature heat in the furnace is suppressed in or prevented from flowing out into the working area 10 through the load port 4.

When the shutter device 17 is subjected to maintenance operations, the screws are unfastened, which fix the bottom plate 30 to the front supports 20a to maintain the arm 19 horizontal. Then, the shutter device 17 is rotated downward about the shaft 31 at the proximal portion, to an inclined state held by the stays 32. At this time, the arm 19 is preferably in the contracted state. However, the arm 19 may remain extended when shutter device 17 is inclined downward, as shown in FIG. 4.

When the shutter device 17 is inclined downward, a wide space for maintenance operations is formed above the shutter device 17. Accordingly, maintenance operations on the shutter device 17, such as those on the port cover 18 and arm 19, can be readily performed.

The extensible/contractible arm 19 linearly moves the port cover 18 of the shutter device 17 between the closing position PB and the waiting position PA laterally shifted therefrom, to open/close the load port 4 of the reaction tube 5. Accordingly, the port cover 18 is easily controlled in stopping actions, thereby reducing the time necessary for opening and closing operations of the shutter device 17. Specifically, linearly moving the heavy port cover 18 allows the port cover 18 to be moved in a shorter time (for example, each of the closing operation and opening operation takes about 10 seconds) and in a smaller

space, as compared to moving the heavy port cover 18 by a swing motion. As a consequence, the vertical heat-processing apparatus 1 improves in throughput and reduces the space needed.

The port cover 18 is provided with a water-cooling structure (cooling structure) in which the cooling-water passage 33 for circulating cooling-water is formed. Accordingly, the port cover 18 is suppressed in or prevented from suffering thermal deformation or thermal degradation. In addition, the arm 19 is suppressed in or prevented from suffering thermal deformation or thermal degradation due to heat conduction through the port cover 18. This increases the durability of the shutter device 17.

The arm 19 can rotate about a supporting portion at the proximal portion from the horizontal set state to the maintenance state PC where it is inclined downward. Accordingly, the port cover 18 or arm 19 can be readily subjected to maintenance operations, thereby improving the operability.

When the shutter device 17 is opened/closed, the controller controls reciprocation of the second arm element 26 relative to the first arm element 24, such that it is performed only when the first arm element 24 is in the casing 21. Specifically, when the port cover 18 is moved for the closing operation from the waiting position PA to the closing position PB, the second arm

element 26 is first moved forward, and then the first arm element 24 is moved forward. When the port cover 18 is moved for the opening operation from the closing position PB to the waiting position PA, the first arm element 24 is first moved backward, and then the second arm element 26 is moved backward. This arrangement prevents dust generated by sliding of the arm 19 from flowing out into the working area 10.

A gas flow is formed from the outside into the inside of the casing 21 through the front opening 52 of the casing 21. This prevents dust generated in the casing 21 from flowing out into the working area 10. As a consequence, it is possible to prevent wafers W handled in the working area 10 from being contaminated with dust generated in the shutter device 17.

FIG. 9 is a side view schematically showing a shutter device according to another embodiment of the present invention. This shutter device 17X includes a pushing mechanism 42 for moving up a port cover 18 at a closing position PB and bringing it into close contact with a load port 4. The pushing mechanism 42 is arranged to move the port cover 18 up and down integratedly with the extensible/contractible arm 19 as a whole. Also in this embodiment, the arm 19 extends and contracts to linearly move the port cover 18 to perform opening and closing operations.

Movable frames 43 movable up and down are

respectively attached to a pair of right and left supports 20, which are disposed at the bottom of a base plate 8 one on either side of the arm 19. The pushing mechanism 42 includes cylinders 42a to drive the movable frames 43. The rear side of the proximal arm element 22 of the extensible/contractible arm 19 is supported to be vertically rotatable, by the movable frames 43 through a shaft 44. The front side of the proximal arm element 22 is detachably connected to the movable frames 43 by screws (not shown).

When the arm 19 is tucked away at a waiting position PA (in a casing 21), it is set at a lower position by the pushing mechanism 42. The arm 19 extends from this state to move the port cover 18 to the closing position PB for the load port 4. Then, the pushing mechanism 42 is activated to move up the arm 19 and bring the port cover 18 into close contact with the lip of the load port 4, thereby closing the load port 4.

As described above, the shutter device 17X shown in FIG. 9 can provide the same operation and effect as in the shutter device 17 shown in FIG. 4. In addition, the shutter device 17X includes the pushing mechanism 42 for moving the arm 19 up and down, to move up the port cover 18 to bring it into contact with the load port 4. Accordingly, the port cover 18 can airtightly close the load port 4 to reliably prevent heat from

flowing out through the load port 4, and further allow the interior of the furnace to be set at a pressure-reduced state.

The vertical heat-processing apparatuses according to the embodiments described above are examples of an application of the present invention. The present invention may be applied to a vertical heat-processing apparatus of another type in the same way. As a target substrate, a semiconductor wafer is handled in the embodiments described above. The present invention is not limited thereto, but may be applied to a glass substrate or LCD substrate.

CLAIMS

1. A vertical heat-processing apparatus for heat-processing a plurality of target substrates all together, the apparatus comprising:

an airtight process chamber configured to accommodate the target substrates, and having a load port at a bottom;

a lid configured to selectively open and close the load port of the process chamber;

a holder configured to hold the target substrates stacked at intervals;

a supply section configured to supply a process gas into the process chamber;

an exhaust section configured to exhaust the process chamber,

a heater configured to heat an atmosphere in the process chamber;

an elevator configured to move the lid up and down, along with the holder placed thereon, which holds the target substrates; and

a shutter device configured to mask the load port after the target substrates are unloaded from the process chamber through the load port,

the shutter device comprising

a port cover configured to selectively closing the load port of the process chamber, and

an actuator including an extensible/contractible

arm that supports and moves the port cover, the actuator being configured to linearly move the port cover by the extensible/contractible arm between a closing position to close the load port and a waiting position laterally shifted from the closing position,

wherein the extensible/contractible arm comprises a proximal portion and a plurality of arm elements supported by the proximal portion and supporting the port cover, and the plurality of arm elements comprise a first arm element reciprocable relative to the proximal portion and a second arm element reciprocable relative to the first arm element, and

the shutter device further comprises a casing configured to accommodate the port cover and the extensible/contractible arm, such that the waiting position is located in the casing.

2. The vertical heat-processing apparatus according to claim 1, wherein the first arm element comprises a linear guide, and the second arm element is configured to slide on the linear guide of the first arm element.

3. The vertical heat-processing apparatus according to claim 2, wherein the proximal portion comprises a linear guide, and the first arm element is configured to slide on the linear guide of the proximal portion.

4. The vertical heat-processing apparatus according to claim 1, wherein the extensible/contractible arm is supported by and rotatable about an axis portion disposed on a proximal side, and is switchable between a set state to be moved between the closing position and the waiting position and a maintenance state to be inclined downward.

5. The vertical heat-processing apparatus according to claim 1, wherein the shutter device further comprises a pushing mechanism configured to bring the port cover into close contact with the load port.

6. The vertical heat-processing apparatus according to claim 5, wherein the pushing mechanism is configured to move the extensible/contractible arm as a whole.

7. The vertical heat-processing apparatus according to claim 1, wherein the shutter device further comprises a coolant passage formed in the port cover, and a supply section configured to supply a coolant into the coolant passage.

8. The vertical heat-processing apparatus according to claim 1, wherein the shutter device further comprises a controller that controls an

operation of the extensible/contractible arm, and the controller is arranged to perform reciprocation of the second arm element relative to the first arm element only when the first arm element is in the casing.

9. The vertical heat-processing apparatus according to claim 1, wherein the shutter device further comprises a controller that controls an operation of the extensible/contractible arm, and the controller is arranged such that: the first arm element is moved forward after the second arm element is moved forward when the port cover is moved from the waiting position to the closing position; and the second arm element is moved backward after the first arm element is moved backward when the port cover is moved from the closing position to the waiting position.

10. The vertical heat-processing apparatus according to claim 1, wherein the casing comprises a first opening formed in a first side of the casing facing the closing position, and a second opening formed in a second side of the casing different from the first side, and the apparatus further comprises a mechanism configured to form a gas flow flowing in through the first opening and flowing out through the second opening.

11. The vertical heat-processing apparatus according to claim 10, wherein the second opening is connected to a gas suction member through a duct.

12. A vertical heat-processing apparatus for heat-processing a plurality of target substrates all together, the apparatus comprising:

an airtight process chamber configured to accommodate the target substrates, and having a load port at a bottom;

a lid configured to selectively open and close the load port of the process chamber;

a holder configured to hold the target substrates stacked at intervals;

a supply section configured to supply a process gas into the process chamber;

an exhaust section configured to exhaust the process chamber,

a heater configured to heat an atmosphere in the process chamber;

an elevator configured to move the lid up and down, along with the holder placed thereon, which holds the target substrates; and

a shutter device configured to mask the load port after the target substrates are unloaded from the process chamber through the load port,

the shutter device comprising

a port cover configured to selectively closing the load port of the process chamber, and

an actuator including an extensible/contractible arm that supports and moves the port cover, the

actuator being configured to linearly move the port cover by the extensible/contractible arm between a closing position to close the load port and a waiting position laterally shifted from the closing position,

wherein the extensible/contractible arm is supported by and rotatable about an axis portion disposed on a proximal side, and is switchable between a set state to be moved between the closing position and the waiting position and a maintenance state to be inclined downward.

13. The vertical heat-processing apparatus according to claim 12, wherein the extensible/contractible arm comprises a proximal portion and a plurality of arm elements supported by the proximal portion and supporting the port cover, and the plurality of arm elements comprise a first arm element reciprocable relative to the proximal portion and a second arm element reciprocable relative to the first arm element.

14. The vertical heat-processing apparatus according to claim 13, wherein the first arm element comprises a linear guide, and the second arm element is configured to slide on the linear guide of the first arm element.

15. The vertical heat-processing apparatus according to claim 14, wherein the proximal portion comprises a linear guide, and the first arm element is

configured to slide on the linear guide of the proximal portion.