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DESCRIPTION

THERMAL PROCESSING SYSTEM AND THERMAL PROCESSING METHOD

TECHNICAL FIELD

The present invention relates to a thermal processing method of processing workpieces, such as semiconductor wafers or the like, by a thermal process and chemical/physical process, and a thermal processing system for carrying out the thermal processing method.

BACKGROUND ART

Generally, various thermal processes including a film deposition process, an etching process, an oxidation process, a diffusion process and a modification process, in fabricating semiconductor integrated circuits, process semiconductor wafers, such as silicon substrates. When those thermal processes are carried out by a batch-type vertical thermal processing system, a plurality of semiconductor wafers are transferred from cassettes each capable of containing a plurality of semiconductor wafers, such as twenty-five semiconductor wafers, to a vertical wafer boat and the semiconductor wafers are stacked in layers on the wafer boat. Some large wafer boat has a capacity to hold about 150 semiconductor wafers at the maximum. When necessary, dummy wafers different from the semiconductor wafers are interposed between the adjacent semiconductor wafers to ensure the uniform flow of gases or to adjust a vertical temperature profile along the height of the wafer boat.

The wafer boat holding the wafers of different types in a vertical arrangement is loaded through a lower end of a processing vessel capable of being evacuated into the processing vessel, and then the processing vessel is sealed. A predetermined process program is executed, process conditions including the flow rate of a processing gas, process pressure and process temperature are controlled according to the process program to carry out a predetermined thermal

process.

A wafer layout program prescribing the layout of wafers in a boat must be specified prior to the thermal process. The wafer layout program prescribes the arrangement of wafers on the wafer boat, positions of dummy wafers, whether or not a dummy wafer is to be placed in a space in the wafer boat corresponding to an empty space, if any, in a cassette and such. As a matter of course, a process program prescribing a thermal process to be carried out must be specified beforehand.

The foregoing conventional thermal processing system requires the operator to enter two kinds of codes, i.e., a code identifying a layout program and a code identifying a process program. Sometimes, the operator enters a wrong code when there are a large number of codes.

DISCLOSURE OF THE INVENTION

The present invention has been made in view of the foregoing problems and it is therefore an object of the present invention to provide a thermal processing system and a thermal processing method that enables selecting a combination of a layout program and a process program by a simple operation.

According to the present invention, a thermal processing system comprises: a processing vessel; a workpiece boat placed in the processing vessel and capable of holding a plurality of workpieces at predetermined positions thereon in vertical arrangement; a layout program storage device storing a plurality of layout programs for placing the workpieces in the workpiece boat in different layouts, respectively identified by layout identification codes and respectively prescribing different layouts; a process program storage device storing a plurality of process programs respectively for processing the workpieces by different thermal processes, respectively identified by process identification codes and respectively prescribing different processes of different process conditions; a job recipe storage device storing a plurality of job recipes identified respectively by job

identification codes, and respectively prescribing combinations of desired layout identification code or codes and desired process identification code or codes selected from the plurality of layout identification codes and the plurality of process identification codes and arranging the selected layout identification code or codes and the selected process identification code or codes in time sequence of execution; and a control unit for executing a control operation to execute the layout program or programs and the process program or programs prescribed by the job recipe corresponding to a job identification code entered from the outside.

The operator needs only to enter a desired job identification code by operating an input device to carry out a desired job for the thermal processing system. When the desired job identification code is entered, the layout program and the process program specified by the job identification code are read from the layout program storage device and the process program storage device and then the layout program and the process program are executed in time sequence of execution represented by the job recipe. Thus, one of various combinations, each of the layout program and the process program can be easily selected simply by selecting the job identification code, and wrong job entering operation can be prevented.

In the thermal processing system according to the present invention, the job recipes stored in the job recipe storage device include those having one or a plurality of process identification codes.

In the thermal processing system according to the present invention, the job recipes stored in the job recipe storage device include those having one or a plurality of layout identification codes.

In the thermal processing system according to the present invention, the processing vessel is a vertical processing vessel having an open lower end.

In the thermal processing system according to the present invention, the job identification code is entered into the

control unit through an input device.

According to the present invention, a thermal processing method of processing workpieces held on a workpiece boat by a thermal process in a processing vessel comprises the steps of: storing a plurality of layout programs for placing the workpieces in the workpiece boat in different layouts, respectively prescribing different layouts of workpieces on the workpiece boat and identified respectively by layout identification codes in a layout program storage device; storing a plurality of process programs for processing the workpieces by different processes, respectively prescribing thermal processes of different process conditions and identified respectively by process identification codes in a process program storage device; storing a plurality of job recipes identified respectively by job identification codes, and respectively prescribing combinations of desired layout identification code or codes and desired process identification code or codes selected from the plurality of layout identification codes and the plurality of process identification codes and arranging the selected layout identification code or codes and the selected process identification code or codes in time sequence of execution in a job recipe storage device; and placing workpieces in the workpiece boat in a layout or layouts prescribed by the layout program or programs specified by a job recipe code entered from the outside, introducing the workpiece boat into the processing vessel, and subjecting the workpieces in the workpiece boat to a thermal process or processes prescribed by a process program or programs specified by the job recipe identified by the job identification code.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic sectional view of a thermal oxidation system in a preferred embodiment according to the present invention;

Fig. 2 is a block diagram of a control system included in a thermal processing system according to the present

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invention;

Fig. 3 is a table showing data stored in a process storage unit;

Fig. 4 is a table showing data stored in a layout storage unit;

Fig. 5 is a table showing data stored in a job recipe storage unit; and

Figs. 6(A) to 6(E) are schematic side elevations of wafer boats holding wafers in different layouts thereon, respectively.

BEST MODE FOR CARRYING OUT THE INVENTION

A thermal processing system and a thermal processing method in preferred embodiments according to the present invention will be described with reference to the accompanying drawings.

Fig. 1 is a schematic sectional view of a thermal oxidation system in a preferred embodiment according to the present invention, Fig. 2 is a block diagram of a control system included in a thermal processing system according to the present invention, Fig. 3 is a table showing data stored in a process storage unit, Fig. 4 is a table showing data stored in a layout storage unit, Fig. 5 is a table showing data stored in a job recipe storage unit, and Figs. 6(A) to 6(E) are schematic side elevations of wafer boats holding wafers in different layouts thereon, respectively.

The thermal processing system 22 has a double-wall processing vessel 28 of a predetermined length including an inner tube 24 of quartz and an outer tube 26 of quartz. A wafer boat 30 of quartz, i.e., a workpiece boat for holding workpieces, is placed in a processing space S surrounded by the inner tube 24. The wafer boat 30 holds semiconductor wafers W, i.e., workpieces. The wafer boat 30 holds dummy wafers also.

A cap 32 covers the open lower end of the processing vessel 28. A rotating shaft 36 is extended through a magnetofluid seal 34 attached to the cover 32, and a rotating

table 38 is attached to the upper end of the rotating shaft 36. A wafer boat 30 is mounted on an insulating tube 40 placed on the table 38. The rotating shaft 36 is attached to an arm 44 included in a boat elevator 42 for vertically moving the rotating shaft 36. The boat elevator 42 moves the rotating shaft 36 vertically together with the cap 32 and the wafer boat 30. Thus, the wafer boat 30 is loaded into the processing vessel 28 through the open lower end of the processing vessel 28. The wafer boat 30 does not need necessarily to be rotatable and may be held in a stationary state.

A manifold 46 of, for example, a stainless steel is joined to the open lower end of the processing vessel 28. A plurality of gas nozzles, three gas nozzles 48A, 48B and 48C in this embodiment, are connected to the manifold 46 to supply necessary gases into the processing vessel 28. The gas nozzles 48A, 48B and 48C are connected to gas supply systems 50A, 50B and 50C, respectively. The gas supply systems 50A, 50B and 50C are provided with flow controllers 52A, 52B and 52C, such as mass-flow controllers, respectively. Although the thermal processing system in this embodiment is provided with the three gas nozzles 48A, 48B and 48C, it goes without saying that the thermal processing system may be provided with any number of gas nozzles when necessary.

Gases supplied through the gas nozzles 48A, 48B and 48C flow upward in processing space S, i.e., wafer holding region, flow downward from the top of the processing space S through a space between the inner tube 24 and the outer tube 26, and are discharged from the processing vessel 28. A discharge port 54 formed in a lower part of the side wall of the outer tube 26 is connected to an evacuating system 52 including a discharge line 56, a pressure control valve 58 and a vacuum pump 60 to evacuate the processing vessel 28.

An insulating wall 64 surrounds the processing vessel 28. A heater 66, heating means, is attached to the inner surface of the insulating wall 64 to heat wafers W placed in the processing vessel 28.

Suppose that the wafer boat 30 holds about one hundred

fifty 8 in. wafers (about one hundred thirty process wafers and about twenty dummy wafers). Then, the diameter of the inner tube is in the range of about 260 to about 270 mm, the diameter of the outer tube 26 is in the range of about 275 to about 285 mm, and the height of the processing vessel 28 is about 1280 mm.

Sealing member 68 and 70, such as O rings, are held between the cap 32 and the manifold 46 and between the manifold 46 and the lower end of the outer tube 26, respectively, for sealing.

A wafer transfer mechanism 82 for loading wafers W into and unloading wafers W from the wafer boat 30 is installed below the processing vessel 28. The wafer transfer mechanism 82 has a transfer arm 84 capable of being vertically moved by a ball screw mechanism. A fork head 86 is supported on the transfer arm 84 for sliding along the arm 84 and for turning about its axis. A plurality of forks 88, for example, five forks 88 in this embodiment, are supported on the fork head 86. Thus, five wafers W at the maximum can be transferred to the wafer boat 30 at a time by the forks 88.

A control system included in the thermal processing system will be described with reference to Fig. 2.

Referring to Fig. 2, the control system has a control unit 2, such as a central processing unit of a computer. The control unit 2 is connected to a heater controller 6, a mechanism controller 8, a gas controller 10, a pressure controller 12, a process program storage device 14, a layout program storage device 16, and a job recipe storage device 72 by buses 4. The heater controller 6 controls the heater 66 of the thermal processing system. The mechanism controller 8 controls the boat elevator 42 for vertically moving the wafer boat 30 for loading and unloading the wafer boat 30 and the wafer transfer mechanism 82 for loading wafers into and unloading wafers from the wafer boat 30. The gas controller 10 controls flow controllers 52A 52B and 52C for controlling the flow of process gases. The pressure controller 12 controls the pressure control valve 58 to control the pressure in the processing

vessel 28. The process program storage device 14 stores a plurality of process programs prescribing various processes. The layout program storage device 16 stores a plurality of layout programs prescribing various layouts of wafers on the wafer boat 30. The job recipe storage device 72 stores a plurality of job recipes, each being a combination of layout identification code or codes representing the layout program or programs and process identification code or codes representing the process program or programs arranged in time sequence of execution. The process program storage device 14, the layout program storage device 16 and the job recipe storage device 72 are formed in the same secondary storage device, such as a hard disk 74.

An input device 18, such as a touch panel or a keyboard, and the control unit 2 for controlling all the operations of the thermal processing system are connected to the bus 4. In some cases, a host computer 20 provides various control commands. The foregoing controllers are representative ones and, actually, various other controllers are connected to the buses 4

Data stored in the storage devices 14, 16 and 17 will be described.

Referring to Fig. 3, the process program storage device 14 stores process programs prescribing actual thermal processes, and process identification codes respectively representing the process programs. In Fig. 3, the process program storage device 14 stores m (m is a positive integer) process programs, and program identification codes P1 to Pm are assigned to the m process programs, respectively. For example, the process program 1 prescribes a film deposition process 1, the process program 2 prescribes a film deposition process 2, the process program 3 prescribes a film deposition process 3, the process program 4 prescribes a checking process, a process program 5 prescribes a seasoning process, and a process program y prescribes a cleaning process.

Each of the process programs prescribes various process conditions including process gases to be used, gas flow rates,

a process temperature, a process pressure and a process time. The film deposition processes 1 to 3 deposit, for example, different types of film on wafers, respectively. The check process checks whether the heater 66, the flow controllers 52A to 52C, the pressure control valve 58 and the like can be operated normally before starting the film deposition process or the like.

The seasoning process is executed, for example, immediately after the cleaning process to stabilize the environment in the processing vessel 28 by supplying a process gas for film deposition into the processing vessel 28 so that the same type of film as that to be deposited on wafers is deposited on the inner surface of the processing vessel 28 before actually depositing a film on the wafers.

The cleaning process removes unnecessary films formed on the inner surface of the processing vessel 28 and the surface of the wafer boat 30.

The foregoing thermal processes are only examples and the thermal processing system is capable of carrying out other various thermal processes including an oxidation-diffusion process, an etching process, a modification process and an annealing process.

Referring to Figs. 4 and 6, the layout program storage device 16 stores layout programs prescribing predetermined layouts of wafers on the wafer boat 30, and layout identification codes respectively representing the layout programs. In Fig. 4, the layout program storage device 16 stores n (n is a positive integer) layout programs, and program identification codes L1 to Ln are assigned to the n layout programs, respectively. The layout programs prescribe different layouts of wafers on the wafer boat 30.

For example, the layout program 1 prescribes a layout 1 as shown in Fig. 6(A). The layout 1 shown in Fig. 6(A) specifies stacking a plurality of dummy wafers DW, for example, five dummy wafers DW in Fig. 6(A), in each of upper and lower end parts of the wafer boat 30, and stacking wafers W in a middle part, between the upper and the lower end part, of

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the wafer boat 30. This layout is referred to as 'middle loading'. The layout program 2 prescribes a layout 2 as shown in Fig. 6(B). The layout 2 shown in Fig. 6(B) specifies stacking a plurality of dummy wafers DW, for example, ten dummy wafers DW in Fig. 6(B), in a lower end part of the wafer boat 30 and stacking wafers W in an upper part of the wafer boat 30. This layout is referred to as 'upper loading'.

The layout program 3 prescribes a layout 3 as shown in Fig. 6(C). The layout 3 shown in Fig. 6(C) specifies stacking a plurality of dummy wafers DW, for example, ten dummy wafers DW in Fig. 6(C), in an upper of the wafer boat 30 and stacking wafers W in a lower part of the wafer boat 30. This layout is referred to as 'lower loading'.

The layout program 4 prescribes a layout 4 as shown in Fig. 6(D). The layout 4 shown in Fig. 6(D) is a modification of the layout 1 shown in Fig 6(A). Some wafer cassette capable of holding twenty-five wafers is not necessarily fully loaded and in some cases some of the twenty-five wafers are missing. Wafers held in such a wafer cassette not fully loaded are transferred to the wafer boat 30 without filling up empty spaces between the wafers with wafers. Consequently, empty spaces 80 not holding any wafers are formed in the wafer boat 30 as shown in Fig. 6(D). This layout is referred to as 'first modified middle loading'.

The layout program 5 prescribes a layout 5 as shown in Fig. 6(E). The layout 5 shown in Fig. 6(E) fills up the empty spaces 80 shown in Fig. 6(D) with dummy wafers DW. This layout is referred to as 'second modified middle loading'.

The foregoing layouts are only examples, and the layout program storage device 16 stores other various layout programs prescribing various different layouts.

The job recipe storage device 72, which is characteristic of the present invention, stores plurality of job recipes as shown in Fig. 5. Each of the recipes is a combination of the selected layout identification code or codes and the selected process identification code or codes arranged in time sequence of execution.

Fig. 5 shows h (h is a positive integer) job recipes and job identification codes J1 to Jh are assigned to the job recipes, respectively. The job identification code J1 identifies a job recipe "L1→P1", which specifies execution of the layout program 1 and the process program 1 in that order. Each of the job recipes is a combination of one or some of the process programs shown in Fig. 3 and one or some of the layout programs shown in Fig. 4 arranged in a desired time sequence of execution. Combinations of the job identification codes and the corresponding job recipes are stored in the job recipe storage device 72.

A thermal processing method of the present invention to be carried out by the thus constructed thermal processing system of the present invention will be described.

The operator who knows the desired combination of the desired layout or layouts of wafers and the desired thermal process or processes enters the job identification code representing the desired combination by operating the input device 18. In some cases, the job identification code is entered by operating the host computer 20.

Then, the control unit 2 reads the job recipe identified by the job identification code from the job recipe storage device 72 and analyzes the contents of the job recipe. Then, the control unit 2 executes the layout program or programs and the process program or programs sequentially in order prescribed by the job recipe.

For example, if the operator enters the job identification code "J1" identifying the job recipe "L1→P1", the wafer transfer mechanism 82 loads process wafers W and dummy wafers DW in the layout 1 shown in Fig. 6(A) into the wafer boat 30. The wafer boat 30 is raised into the processing vessel 28 to load the wafers W into the processing vessel 28, and then the process program 1 is executed. The wafer transfer mechanism 82 operates similarly to load wafers into the wafer boat 30 for the following operations prescribed by the job recipes.

If the job identification code "J2" identifying the job

recipe "L2→P3" is entered, process wafers W and dummy wafers DW are loaded into the wafer boat 30 in the layout 2 shown in Fig. 6(B), and then the process program 3 is executed.

Similarly, if the job identification code "J3" identifying the job recipe "L3→P1→P2→P3" is entered, process wafers W and dummy wafers DW are loaded into the wafer boat 30 in the layout 3 shown in Fig. 6(C), and then the process programs 1, 2 and 3 are executed in that order. Such a processing mode in which a plurality of process programs, such as three process programs, are executed, is used for forming a multilayer structure of, for example, an oxide film, a nitride film and an oxide film.

Similarly, if the job identification code "J4" identifying the job recipe "P4→L2→P2→P1" is entered, the process program 4 prescribing the check process is executed with the processing vessel 28 being in an unloaded state to ensure that the component parts of the thermal processing system operates normally. When it is confirmed that all the component parts operates normally, process wafers W and dummy wafers DW are loaded into the wafer boat 30 in the layout 2 shown in Fig. 6(B), and then the process programs 2 and 1 are executed in that order.

Similarly, if the job identification code "J5" identifying the job recipe "L4→P3→P6" is entered, process wafers W and dummy wafers DW are loaded into the wafer boat 30 in the layout 4 shown in Fig. 6(D), and then the process program 3 and the process program 6 prescribing the cleaning process are executed in that order. Naturally, the wafer boat 30 is lowered to unload the wafers W from the processing vessel 28 before executing the process program 6 prescribing the cleaning process.

Similarly, if the job identification code "J6" identifying the job recipe "L1→P1→L2→P3" is entered, process wafers W and dummy wafers DW are loaded into the wafer boat 30 in the layout 1 shown in Fig. 6(A), and then the process program 1 is executed. After the completion of the process program 1, the wafer boat is taken out of the processing vessel

28, the same processing wafers W are loaded into the wafer boat 30 in the layout 2 shown in Fig. 6(B), and then the process program 3 is executed.

Thus, wavers W can be subjected to different processes in different layouts.

Thus, the operator needs to enter simply only one job identification code to select one job recipe or a plurality of recipes to subject wafers to desired processes in desired layouts.

Since the operator needs to enter only one job identification code, the possibility of wrong job entering operation is less than that will be made by the conventional method.

Although the present invention has been described as applied to a thermal processing system provided with a double-wall processing vessel, there is not any particular restrictions on the construction of the processing vessel, and the present invention is applicable to any thermal processing system, provided that the thermal processing system is provided with a batch type processing vessel. For example, the present invention is applicable to a thermal processing system provided with a single-wall processing vessel, a processing vessel that receives process gases a through the bottom thereof and discharges the process gases through the top thereof or a processing vessel that receives process gases a through the top thereof and discharges the process gases through the bottom thereof. The present invention is applicable not only to a thermal processing system provided with a vertical processing vessel, but also to a thermal processing system provided with a horizontal processing vessel.

The workpieces that can be processed by the present invention are not limited only to semiconductor wafers, but may be LCD substrates, glass substrates and such.

As apparent from the foregoing description, the thermal processing system and the thermal processing method of the present invention have the following effects.

When the operator needs to enter only a desired job identification code by operating, for example, an input device, to make the control unit read the layout program or programs and process program or programs represented by the job identification code respectively from the layout program storage device and the process program storage device, and execute the layout program or programs and the process program or programs sequentially in the time sequence of execution prescribed by the job recipe. Thus, various combinations of the layout program or programs and the process program or programs can be selected simply by entering the job identification code and hence the possibility of wrong jog entering operations can be reduced.

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CLAIMS:

1. A thermal processing system (22) comprising:

a processing vessel (28);

a workpiece boat (30) placed in the processing vessel (28) and capable of holding a plurality of workpieces (W) at predetermined positions thereon in vertical arrangement;

a layout program storage device (16) storing a plurality of layout programs for placing the workpieces in the workpiece boat in different layouts, respectively identified by layout identification codes (L1 to Ln) and respectively prescribing different layouts;

a process program storage device (14) storing a plurality of process programs respectively for processing the workpieces by different thermal processes, respectively identified by process identification codes (P1 to Pm) and respectively prescribing different processes of different process conditions;

a job recipe storage device (72) storing a plurality of job recipes identified respectively by job identification codes (J1 to Jh), and respectively prescribing combinations of desired layout identification code or codes and desired process identification code or codes selected from the plurality of layout identification codes (L1 to Ln) and the plurality of process identification codes (P1 to Pm) and arranging the selected layout identification code or codes and the selected process identification code or codes in time sequence of execution; and

a control unit (2) for executing a control operation to execute the layout program or programs and the process program or programs prescribed by the job recipe corresponding to a job identification code entered from the outside.

2. The thermal processing system (22) according to claim 1, wherein

the job recipes stored in the job recipe storage device (72) include those having one or a plurality of process identification codes (P1 to Pm).

3. The thermal processing system (22) according to claim 1, wherein

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the job recipes stored in the job recipe storage device (72) include those having one or a plurality of layout identification codes (L1 to Ln).

4. The thermal processing system according to claim 1, wherein

the processing vessel (28) is a vertical processing vessel having an open lower end.

5. The thermal processing system according to claim 1, wherein

the job identification code is entered into the control unit (2) through an input device (18).

6. A thermal processing method of processing workpieces held on a workpiece boat (30) by a thermal process in a processing vessel (28), said thermal processing method comprising the steps of:

storing a plurality of layout programs for placing the workpieces (W) in the workpiece boat (30) in different layouts, respectively prescribing different layouts of workpieces on the workpiece boat (30) and identified respectively by layout identification codes (L1 to Ln) in a layout program storage device (16);

storing a plurality of process programs for processing the workpieces by different processes, respectively prescribing thermal processes of different process conditions and identified respectively by process identification codes (P1 to Pm) in a process program storage device (14);

storing a plurality of job recipes identified respectively by job identification codes (J1 to Jh), and respectively prescribing combinations of desired layout identification code or codes and desired process identification code or codes selected from the plurality of layout identification codes (L1 to Ln) and the plurality of process identification codes (P1 to Pm) and arranging the selected layout identification code or codes and the selected process identification code or codes in time sequence of execution in a job recipe storage device (72); and

placing workpieces (W) in the workpiece boat (30) in a layout or layouts prescribed by the layout program or programs specified by a job recipe code entered from the outside,

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introducing the workpiece boat (30) into the processing vessel (28), and subjecting the workpieces in the workpiece boat (30) to a thermal process or processes prescribed by a process program or programs specified by the job recipe identified by the job identification code (J1 to Jh).