

THERMAL PROCESSING APPARATUS

Technical Field

The present invention relates to a fixing method of a heater for a thermal processing apparatus and the thermal processing apparatus itself, which conducts a heat treatment to an object to be processed, such as a semiconductor wafer.

Background Art

10 A thermal processing apparatus is used for conducting various heat treatments including a film-forming process and an oxidation process to an object to be processed, such as a semiconductor wafer, in a manufacturing process of the semiconductor wafers. The thermal processing apparatus has a reaction vessel, which contains the semiconductor wafer. A heating member including a heater and an
15 heat insulating body is provided so as to surround the reaction vessel. The reaction vessel is heated to a predetermined temperature by means of the heater, so that the semiconductor wafer undergoes the various heat treatments.

20 As a heater of the thermal processing apparatus, for example, a longitudinal heater element has been used, wherein a wire resistance heating element is sealed in a sealing member. The heat insulating body is made of for example stainless steel (SUS). A plurality of holes is formed in the heat insulating body. A heater element is inserted into
25 each hole of the insulating body. The plurality of holes are arranged in such a manner that each heater element is located at a predetermined distance from the reaction vessel.

As described above, in the conventional thermal processing apparatus, the heater elements are directly inserted into the holes of the
30 heat insulating body. Thus, the heater elements and inside walls of the holes of the heat insulating body rub with each other, so that contaminant such as metal powder (metal contamination) may be generated. If a heat treatment is conducted under a condition wherein the contaminant has been generated, the contaminant may be
35 deposited on the semiconductor wafer. In that case, the performance of manufactured semiconductor devices may be deteriorated, and hence

the yield may be deteriorated. Actually, when the contaminant is metal contamination, the performance of manufactured semiconductor devices may be deteriorated significantly. In addition, when the heater elements and the inside walls of the holes of the heat insulating body rub with each other, the heater elements themselves may be broken down.

In addition, an end portion of the heater element is connected to a cable, which is connected to a power supply. However, if the cable bears a load, for example when the cable ensnarls another component, the heater element may be pulled by the cable and broken down.

SUMMARY OF THE INVENTION

The present invention has been made in view of those problems and it is therefore an object of the present invention to provide a fixing method of a heater for a thermal processing apparatus and a thermal processing apparatus itself, wherein contaminant generation can be prevented.

In addition, it is another object of the present invention to provide a fixing method of a heater for a thermal processing apparatus and a thermal processing apparatus itself, wherein heater breakage can be prevented.

The present invention is a thermal processing apparatus comprising: a reaction vessel in which an object to be processed is contained; a heat insulating body provided so as to surround the reaction vessel; a plurality of holes provided in the heat insulating body; a plurality of annular spacer members, each of which is provided in each of the plurality of holes; and a plurality of heater elements, each of which is inserted in each of the plurality of annular spacer members.

According to the present invention, the plurality of heater elements is fixed by the plurality of annular spacer members. Thus, the heater elements don't rub with inside walls of the holes of the heat insulating body, so that no contaminant may be generated. In addition, the heater elements may not be broken down.

Preferably, the spacer member has elasticity. For example, the spacer member is an O-ring.

For example, the heater element has a linear tubular portion. In

the case, it is preferable that the linear tubular portions of the heater elements are arranged at predetermined intervals from the reaction vessel.

Alternatively, the present invention is a thermal processing
5 apparatus comprising: a reaction vessel in which an object to be processed is contained; a heat insulating body provided so as to surround the reaction vessel, made of metal; a plurality of holes provided in the heat insulating body; and a plurality of heater elements, each of which is inserted in each of the plurality of holes; wherein inside
10 wall surfaces of the plurality of holes are coated with ceramics.

According to the present invention, the plurality of heater elements comes in contact with the inside walls of the holes of the heat insulating body coated with the ceramics. That is, the plurality of heater elements doesn't come in contact with any metal part of the heat
15 insulating body. Thus, no metal contamination (contaminant) may be generated. In addition, there is less possibility that the heater elements be broken down.

Preferably, the ceramics is alumina, silica or yttria.

Preferably, the ceramics is porous. In the case, thermal shock
20 resistance may be improved.

In addition, preferably, a surface of the heat insulating body on a side of the reaction vessel is coated with ceramics. In the case, it can be completely prevented that the heater elements come in contact with the metal surface of the heat insulating body, so that it can be prevented
25 that metal contamination be generated. In addition, there is much less possibility that the heater elements be broken down.

In addition, preferably, the heater element is connected to a cable, and the cable is fixed to an apparatus outside wall in a vicinity of an end portion of the heater element by means of a fixing member. In the
30 case, even if the cable bears a load, the heater element rarely or never is broken down. In addition, in the case, the cables are in good order, and hence not likely to ensnarl.

For example, the fixing member is a tie wrap.

Alternatively, the present invention is an assembling method of a
35 thermal processing apparatus including: a reaction vessel in which an object to be processed is contained; a heat insulating body provided so

as to surround the reaction vessel; a plurality of holes provided in the heat insulating body; a plurality of annular spacer members, each of which is provided in each of the plurality of holes; and a plurality of heater elements, each of which is inserted in each of the plurality of annular spacer members; the assembling method comprising: arranging the plurality of annular spacer members in the plurality of holes, respectively; and inserting the plurality of heater elements in the plurality of annular spacer members, respectively.

According to the present invention, the plurality of heater elements is fixed by the plurality of annular spacer members. Thus, the heater elements don't rub with inside walls of the holes of the heat insulating body, so that no contaminant may be generated. In addition, the heater elements may be not broken down.

Preferably, the assembling method further comprises: fixing a cable connected to the heater element to an apparatus outside wall in a vicinity of an end portion of the heater element by means of a fixing member.

Alternatively, preferably, the assembling method further comprises: fixing a cable connected to the heater element to an apparatus outside wall in a vicinity of an end portion of the heater element by means of a tie wrap.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic sectional view of a thermal processing apparatus of an embodiment according to the present invention;

Fig. 2 is a perspective view of a heat insulating body of the embodiment according to the present invention;

Fig. 3 is a perspective view showing a situation wherein heater elements are inserted into holes of the heat insulating body of the embodiment according to the present invention;

Fig. 4 is an enlarged sectional view of a hole into which a heater element is inserted, the hole being one of the holes of the heat insulating body of the embodiment according to the present invention;

Fig. 5 is a side view of a heater element of the embodiment according to the present invention;

Fig. 6 is a side view showing a connecting situation of a heater

element and a cable of the embodiment according to the present invention; and

Fig. 7(a) is a perspective view of a first subheater of the embodiment according to the present invention; and

5 Fig. 7(b) is a side view of the first subheater of the embodiment according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, a fixing method of a heater for a thermal processing
10 apparatus and the thermal processing apparatus according to an embodiment of the present invention are explained regarding a batch type of longitudinal thermal processing apparatus as shown in Fig. 1.

As shown in Fig. 1, a thermal processing apparatus 1 has a
reaction tube 2, which is substantially cylindrical. A longitudinal
15 direction of the reaction tube 2 is oriented vertically. The reaction tube 2 has a double tube structure, which consists of an inner tube 3, and an outer tube 4 covering the inner tube 3 with a predetermined gap. The outer tube 4 has a ceiling. The inner tube 3 and the outer tube 4 are made of a thermal insulating material, such as quartz.

20 A cylindrical manifold 5 made of stainless steel (SUS) is arranged under the outer tube 4. The manifold 5 is hermetically connected to a lower end of the outer tube 4. The inner tube 3 is supported by a supporting ring 6, which is integrated with the manifold 5 to protrude from an inside wall of the manifold 5.

25 A lid 7 is arranged under the manifold 5. The lid 7 is adapted to be moved up and down by means of a boat elevator 8. When the lid 7 is moved up by the boat elevator 8, a lower end of the manifold 5 is closed.

A rotational shaft 9 is provided at the lid 7 to penetrate the lid 7.
30 The rotational shaft 9 is rotated by a motor M. A rotatable turn table 10 is formed on the rotational shaft 9. A wafer boat 12 made of for example quartz is placed on the turn table 10 via a moisture retention unit 11. A plurality of semiconductor wafers W as objects to be processed is arranged in the wafer boat 12 in a vertical direction at
35 predetermined intervals. Thus, when the rotational shaft 9 is rotated by the motor M, the wafer boat 12 is rotated via the turn table 10 and the

moisture retention unit 11. That is, the semiconductor wafers W are rotated.

A plurality of process-gas introducing pipes 13 penetrates a side wall of the manifold 5 (although only one process-gas introducing pipe 13 is shown in Fig. 1 for the convenience of description). The process-gas introducing pipes 13 extend into the inner tube 3. For example, as shown in Fig. 1, the process-gas introducing pipes 13 penetrate the side wall of the manifold 5 at a lower portion with respect to the supporting ring 6 (the inner tube 3), and tip portions of the process-gas introducing pipes 13 are bent upwardly along the inner tube 3. Thus, a process gas supplied from a gas supplying source not shown is introduced into the inner tube 3 through the process-gas introducing pipes 13.

A gas-discharging pipe 14 is connected to the side wall of the manifold 5. The gas-discharging pipe 14 is connected to the side wall of the manifold 5 at an upper portion with respect to the supporting ring 6, and is communicated with a space formed between the inner tube 3 and the outer tube 4 of the reaction tube 2. Thus, a gas to be discharged in the reaction tube 2 is adapted to be discharged from the reaction tube 2 to an outside of the thermal processing apparatus 1 through the space between the inner tube 3 and the outer tube 4 and through the gas-discharging pipe 14. The gas-discharging pipe 14 is connected to a gas-discharging unit consisting of a vacuum pump not shown and so on. The gas-discharging unit can set a pressure in the reaction tube 2 to a predetermined pressure.

A heat insulating body 15 made of stainless steel (SUS) is provided around the reaction tube 2 so as to surround the reaction tube 2. A perspective view of the heat insulating body 15 is shown in Fig. 2. As shown in Fig. 2, the heat insulating body 15 consists of a cylindrical main body 15a, a ceiling plate 15b and a bottom plate 15c. A diameter of the main body 15a is larger than that of the reaction tube 2. The ceiling plate 15b is a discoid plate covering an upper portion of the main body 15a. The bottom plate 15c is an annular plate, whose inner circumference has a size corresponding to an outside wall of the reaction tube 2. A cooling-medium way not shown (for example, a cooling-water way) is provided in the main body 15a of the heat

insulating body 15. Thus, if cooling water is supplied into the cooling-water way, the temperature of the reaction tube 2 can be cooled.

5 A plurality of holes 16a is formed in the ceiling plate 15b of the heat insulating body 15. The plurality of holes 16a is formed along the periphery of the ceiling plate 15b at the same interval of for example several millimeters. In addition, a plurality of holes 17a is formed in the bottom plate 15c of the heat insulating body 15, at positions corresponding to the positions of the plurality of holes 16a (at positions
10 just under the plurality of holes 16a in a vertical direction).

Then, as shown in Fig. 3, heater elements 18 are vertically inserted into the holes 16a and the holes 17a. That is, the heater elements 18 are arranged to penetrate the ceiling plate 15b and the bottom plate 15c of the heat insulating body 15. Herein, not all the
15 heater elements 18 are shown in Fig. 3 for easier understanding of an insert state of the heater elements 18. The heater for the thermal processing apparatus is formed by the plurality of heater elements 18.

In this embodiment, holes 16b are formed in the ceiling plate 15b, into which a first subheater is inserted. In addition, holes 17b are
20 formed in the bottom plate 15c, into which second subheaters are inserted.

Then, an O-ring 19 is arranged in each hole 16a, 17a. Fig. 4 is a schematic view of a hole 16a and the vicinities, into which a heater element 18 is inserted. As shown in Fig. 4, an O-ring 19 is arranged on
25 an inside wall of the hole 16a. The heater element 18 is inserted into the O-ring 19. Thus, the heater element 18 is strongly fixed to the inside wall of the hole 16a via the O-ring 19, so that the heater element 18 doesn't move or jolt in the hole 16a. Thus, the heater element 18 and the inside wall of the hole 16a don't rub with each other, which
30 reduces or removes a possibility that powder (contaminant) is generated. In addition, since the heater element 18 and the inside wall of the hole 16a don't rub with each other, a possibility that the heater element 18 is broken down is reduced or removed. Although the hole 16a is explained, the hole 17a is the same as the hole 16a.

35 The inside wall of the heat insulating body 15 is coated with ceramics. Since the inside wall of the heat insulating body 15 is coated

with ceramics, the heater element 18 never comes in contact with a metal surface (stainless steel) of the heat insulating body 15. Thus, metal contamination is not generated. In addition, since the heater element 18 doesn't come in contact with the metal surface of the heat insulating body 15, the heater element 18 is harder to be broken down. As the ceramics, for example, alumina, silica or yttria may be used. The ceramics is formed as porous. When the ceramic is porous, thermal shock resistance may be improved.

Fig. 5 shows a schematic view of the heater element 18. As shown in Fig. 5, the heater element 18 comprises a resistance heating body 18a and a sealing member 18b. The resistance heating body 18a is formed by for example a linear flexible wire of a high purity carbon. The carbon wire is formed by twisting (braiding) a plurality of strands of carbon fibers of about 10 μm in diameter. The sealing member 18b is made of ceramics, and seals the resistance heating body 18a. In the present embodiment, the carbon wire is sealed in a transparent quartz tube having an outside diameter of ten-some millimeters. Electrode members 20 are connected to opposite ends of the resistance heating body 18a. The sealing member 18b seals an end of one electrode member 20 to an end of the other electrode member 20, so that the resistance heating body 18a is sealed in the sealing member 18b.

The electrode members 20 are connected to outside cables 21. The cables 21 are connected to an electric power supply not shown. A connecting state of the heater element 18 and the cable 21 is shown in Fig. 6. As shown in Fig. 6, the electrode member 20 connected to the heater element 18 is connected to a core wire 21a of the cable 21. The electrode member 20 and the core wire 21a are connected to each other by for example brazing or contact bonding. Then, electric power is supplied from the electric power source to the resistance heating body 18a via the cables 21 and the electrode members 20, so that the heater element 18 is heated.

In addition, the cable 21 connected to the heater element 18 is fixed to an outside wall or an outside-wall cover (not shown) in the vicinity of an end of the heater element 18, by means of a fixing member 22. As the fixing member 22, for example, a tie wrap may be used. In the case, the cable 21 is clamped by the tie wrap to be fixed to

the outside wall or the outside-wall cover. As described above, since the cable 21 is fixed to the outside wall or the outside-wall cover in the vicinity of an end of the heater element 18 by means of the fixing member 22, even if the cable 21 hitches on another component and bears a load, there is no possibility that the heater element 18 is broken down. In addition, since the cable 21 is fixed in the vicinity of an end of the heater element 18, the cables 21 are in good order, and hence not likely to ensnarl.

In addition, as a method of supplying electric power from an electric power source to the heater elements 18, all the heater elements 18 may be connected in a parallel circuit or a series circuit and electric power may be supplied from a common electric power source thereto. Alternatively, the heater elements 18 may be divided into a plurality of groups, heater elements 18 in each group may be connected in a series circuit, and the series heater elements 18 may be connected in a parallel circuit.

A platelike first subheater 23 is provided under a ceiling part (ceiling plate 15b) of the heat insulating body 15, oppositely to the reaction tube 2. Fig. 7(a) shows a perspective view of the first subheater 23. Fig. 7(b) shows a side view of the first subheater 23. As shown in Figs. 7(a) and 7(b), the first subheater 23 is formed by inserting a resistance heating body 23b into a plate body 23a having a thickness of about 8 mm. The plate body 23a is made of quartz. The resistance heating body 23b is formed by for example a carbon wire, in the same manner as the above resistance heating body 18a. Two quartz tubes 24 are welded at two peripheral positions of the plate body 23a. The quartz tubes 24 are connected to an electric power source not shown via cables 25. The quartz tubes 24 of the first subheater 23 are inserted into the holes 16b provided in the heat insulating body 15. The first subheater 23 is supported by the ceiling portion of the heat insulating body 15 via one or more supports 26.

Second subheaters 27 are provided at a lower-end part (bottom plate 15c) of the heat insulating body 15. The second subheater 27 is formed by a heater element shorter than the heater element 18. The second subheaters 27 are inserted into the holes 17b provided inner than the holes 17a. An O-ring 19 is arranged in each hole 17b. The

second subheater 27 is fixed by the O-ring 19. The second subheater 27 is connected to an electric power source not shown via cables 28. In addition, the cables 28 are fixed to the outside wall or the outside-wall cover in the vicinity of an end of the second subheater 27 by a fixing member 22.

A controlling part not shown is connected to the boat elevator 8, the motor M, the process-gas introducing pipes 13, the heater elements 18 (cables 21) and the first subheater 23 (cables 25), the second subheaters 27 (cables 28). The controlling part consists of a micro processor, a process controller and so on. The controlling part measures a temperature, a pressure and so on at each component of the thermal processing apparatus 1. Then, based on the measured data, the controlling part outputs a control signal or the like to each component, in order to control the component.

Next, a thermal process conducted by the thermal processing apparatus 1 as structured above is explained simply. At first, a predetermined number of semiconductor wafers W are contained in the wafer boat 12, in a state wherein the lid 7 has been moved down by the boat elevator 8. Then, the semiconductor wafers W are loaded into the reaction tube 2 (inner tube 3) by moving up the boat elevator 8. Then, a temperature in the reaction tube 2 is raised to a predetermine temperature by the heater elements 18, the first subheater 23 and the second subheaters 27. At the same time, a pressure in the reaction tube 2 is set to a predetermined pressure by the gas-discharging unit not shown connected to the gas-discharging pipe 14.

After the inside of the reaction tube 2 is stabilized at the predetermined pressure and the predetermined temperature, the process gas is supplied from the process-gas supplying pipes 13, so that the predetermined thermal process (heat treatment) is conducted. In addition, during the thermal process, the wafer boat 12 is rotated by the motor M. After the thermal process, the temperature in the reaction tube 2 is lowered to a predetermine temperature, the pressure in the reaction tube 2 is returned to a normal pressure, and the wafer boat 12 (semiconductor wafers W) is unloaded from the reaction tube 2.

As described above, according to the present embodiment, the O-rings 19 are arranged on the inside walls of the holes 16a and the

holes 17a (and the holes 16b and the holes 17b), and the heater elements 18 (and the second subheaters 27) are inserted into the O-rings 19. Thus, the heater elements 18 (the second subheaters 27) are strongly fixed, and hence don't move or jolt in the holes 16a and the holes 17a (the holes 16b and the holes 17b). Thus, the heater elements 18 (the second subheaters 27) and the inside walls of the holes 16a and the holes 17a (the holes 16b and the holes 17b) don't rub with each other, which reduces or removes a possibility that powder (contaminant) is generated. In addition, a possibility that the heater elements 18 (the second subheaters 27) are broken down is reduced or removed.

According to the present embodiment, since the cables 21 (cables 28) are fixed to the outside wall or the outside-wall cover in the vicinities of the ends of the heater elements 18 (the second subheaters 27) by means of the fixing members 22, there is no possibility that the heater elements 18 (the second subheaters 27) are broken down. In addition, the cables 21 (cables 28) are in good order, and hence not likely to ensnarl.

According to the present embodiment, since the inside wall of the heat insulating body 15 is coated with ceramics, the heater elements 18 never come in contact with any metal surface of the heat insulating body 15. Thus, metal contamination is not generated. In addition, since the heater elements 18 don't come in contact with any metal surface of the heat insulating body 15, the heater elements 18 are harder to be broken down. In addition, since the ceramic is porous, thermal shock resistance of the heat insulating body 15 may be improved.

In addition, according to the present embodiment, the first subheater 23 and the second subheaters 27 are arranged in the upper portion and the lower portion of the reaction tube 2, respectively. Thus, the temperature in the reaction tube 2 can be made uniform.

Herein, the present invention is not limited to the above embodiment. The present invention can be variously changed, modified and/or applied. Applicable other embodiments of the present invention are explained below.

In the above embodiment, the O-rings are arranged on the

inside walls of the holes 16a and the holes 17a. However, the O-rings 19 may be arranged on at least one of the inside walls of the holes 16a and the inside walls of the holes 17a. If the O-rings 19 are arranged on the at least one, the heater elements 18 are strongly fixed, so that the
5 heater elements 18 don't move or jolt in the holes.

Alternatively, although the O-rings 19 are arranged on the inside walls of the holes 16a and the holes 17a in the above embodiment, the inside walls of the holes 16a and the holes 17a may be coated with ceramics instead of arranging the O-rings on the inside walls of the holes
10 16a and the holes 17a. In the case, even if the heater elements 18 and the inside walls of the holes 16a and the holes 17a rub with each other, since the heater elements 18 don't come in contact with any metal surface of the heat insulating body 15, it can be prevented that metal contamination is generated.

Although the straight heater elements 18 penetrating the holes
15 16a and the holes 17a are used in the above embodiment, the heater elements 18 may be U-shaped. In the case, for example, a U-shaped heater element may be attached to the thermal processing apparatus 1 by inserting the U-shaped heater element into two adjacent holes 16a.
20 In addition, the area to be heated may be vertically divided into two portions, in such a manner that the heater elements 18 inserted into the holes 16a heat the upper portion of the area and the heater elements 18 inserted into the holes 17a heat the lower portion of the area.

In the above embodiment, the resistance heating body 18a of
25 the heater element 18 is formed by the carbon wire. However, the resistance heating body 18a may be another linear flexible resistance heating body made of another high purity material, instead of the carbon wire.

In the above embodiment, the thermal processing apparatus is
30 batch type and longitudinal type, and has a double tube structure wherein the reaction tube 2 consists of the inner tube 3 and the outer tube 4. However, the present invention is also applicable to a thermal processing apparatus having a single tube structure. The objects to be processed are not limited to semiconductor wafers W and may be, for
35 example, glass substrates for liquid crystal displays.

What is claimed is:

1. A thermal processing apparatus comprising:
a reaction vessel in which an object to be processed is contained;
a heat insulating body provided so as to surround the reaction vessel;
a plurality of holes provided in the heat insulating body;
a plurality of annular spacer members, each of which is provided in each of the plurality of holes; and
a plurality of heater elements, each of which is inserted in each of the plurality of annular spacer members.
2. A thermal processing apparatus according to claim 1, wherein the spacer member has elasticity.
3. A thermal processing apparatus according to claim 2, wherein the spacer member is an O-ring.
4. A thermal processing apparatus according to any of claims 1 to 3, wherein
the heater element has a linear tubular portion.
5. A thermal processing apparatus according to claim 4, wherein the linear tubular portions of the heater elements are arranged at predetermined intervals from the reaction vessel.
6. A thermal processing apparatus comprising:
a reaction vessel in which an object to be processed is contained;
a heat insulating body provided so as to surround the reaction vessel, made of metal;
a plurality of holes provided in the heat insulating body; and
a plurality of heater elements, each of which is inserted in each of the plurality of holes;
wherein inside wall surfaces of the plurality of holes are coated with ceramics.

7. A thermal processing apparatus according to claim 6, wherein the ceramics is alumina, silica or yttria.
8. A thermal processing apparatus according to claim 6 or 7, wherein the ceramics is porous.
9. A thermal processing apparatus according to any of claims 1 to 8, wherein a surface of the heat insulating body on a side of the reaction vessel is coated with ceramics.
10. A thermal processing apparatus according to any of claims 1 to 9, wherein the heater element is connected to a cable, and the cable is fixed to an apparatus outside wall in a vicinity of an end portion of the heater element by means of a fixing member.
11. A thermal processing apparatus according to claim 10, wherein the fixing member is a tie wrap.
12. An assembling method of a thermal processing apparatus including:
 - a reaction vessel in which an object to be processed is contained;
 - a heat insulating body provided so as to surround the reaction vessel;
 - a plurality of holes provided in the heat insulating body;
 - a plurality of annular spacer members, each of which is provided in each of the plurality of holes; and
 - a plurality of heater elements, each of which is inserted in each of the plurality of annular spacer members,the assembling method comprising:
 - arranging the plurality of annular spacer members in the plurality of holes, respectively; and
 - inserting the plurality of heater elements in the plurality of annular spacer members, respectively.

13. An assembling method according to claim 12, further comprising fixing a cable connected to the heater element to an apparatus outside wall in a vicinity of an end portion of the heater element by means of a fixing member.
14. An assembling method according to claim 12, further comprising fixing a cable connected to the heater element to an apparatus outside wall in a vicinity of an end portion of the heater element by means of a tie wrap.