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THERMAL TREATMENT APPARATUS AND METHOD

The present invention relates to apparatus for thermal treatment techniques for semiconductor wafers, such as thermal oxidation treatment, diffusion treatment, CVD (Chemical Vapour Deposition) treatment, annealing, treatment and the like.

According to the present invention, there is provided a thermal treatment apparatus having a horizontally extending furnace tube for subjecting wafers to a thermal treatment, said furnace tube having an opening, a loader disposed on the opening side of said furnace for carrying a plurality of wafer jigs from outside of said furnace tube to inside of said furnace tube, wherein said loader includes a fork extending in the horizontal direction and having two end portions, with one end portion adapted to have said plurality of wafer jigs placed thereon, first means for supporting the other end portion of the fork and for moving the fork in the horizontal direction, said first means having second means for vertically moving said fork with respect to said furnace tube and having third means for adjusting a gradient of said fork with respect to said horizontally extending furnace tube.

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The invention will be further described by way of example with reference to Figs. 1 to 16 of the accompanying illustrative drawings, in which:

5 Fig. 1 is a perspective view of a thermal treatment apparatus according to the present invention;

Fig 2 is a perspective view of a soft landing loader for the apparatus of Fig. 1.;

Fig. 3 is a perspective view of the wafer jig indicated in Fig. 2;

10 Figs. 4 to Fig. 6(A), Fig. 6(B) and Fig.6(C) further illustrate the soft landing loader;

Fig. 7(A) to Fig. 7(G) illustrate the operation of a thermal treatment apparatus according to the present invention.

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Fig. 8 is a sectional view of a fork of a soft landing loader in the thermal treatment apparatus particularly showing the fork being inserted into a process tube;

5 Fig. 9 (A) to Fig. 9 (G) illustrate the operation of a thermal treatment apparatus according to the invention;

Fig. 10 (A) to Fig. 10 (C) illustrate the positions of the fork of a soft landing loader in the operation of the apparatus;

10 Fig. 11 illustrates the operation of the fork when the soft landing loader is in each of three different modes;

Fig. 12 is a front view of a control panel for the soft landing loader; and

15 Fig. 13 to Fig. 16 illustrate operation sequences of the soft landing loader of thermal treatment apparatus according to the present invention in the respective modes of Fig. 11.

Fig. 1 is a perspective view of a thermal treatment
20 apparatus 100 according to the present invention. In the figure, a reference numeral 97 designates a thermal treatment furnace which is employed as, e.g., a diffusion furnace for the thermal diffusion treatment for a semiconductor wafer, a thermal oxidation furnace for
25 forming a thermal oxidation film on a semiconductor

wafer, a CVD furnace for forming a CVD film on a semiconductor wafer or an annealing furnace for annealing a semiconductor wafer. The thermal treatment furnace has three process tubes 102 disposed in the upper, intermediate and lower stages respectively. Also the thermal treatment furnace 97 has a control panel 97A and the like disposed on a side thereof for a control system for controlling the thermal treatment furnace, and a doping cabinet 98 disposed in the rear part thereof.

Moreover, a reference numeral 101 denotes a soft landing loader, and three soft landing loaders are disposed in the upper, intermediate and lower stages in correspondence with the three process tubes 102 of the thermal treatment furnace 97. A reference numeral 101A designates a control panel for controlling the soft landing loaders.

The thermal treatment technique using this apparatus will be described hereinunder through a detailed description of one of the soft landing loaders 101.

Fig. 2 is a perspective view illustrating, in detail, the soft landing loader 101 in the thermal treatment apparatus 100 according to the present invention. The soft landing loader 101 is disposed adjacent to the opening side of one of the process tubes 102, made of quartz, of the thermal treatment furnace 97,

not shown in detail, and is adapted to be capable of loading as well as unloading wafers 104, forming the objects to be treated, mounted in alignment on a wafer jig 103 made of quartz, shown in Fig. 10, together with the wafer jig 103. The soft landing loader 101 has a base 105 and a rear wall 106 vertically disposed in the rear part of the base. The rear wall 106 has a pair of upper and lower guide rails 107 extending in the axial direction (referred to as "longitudinal direction", hereinafter) of the quartz process tube 102. The guide rails 107 are slidably fitted with upper and lower support plates 109, 110, respectively, integrally connected by means of a pair of guide rods 108 extending vertically, as shown in Fig. 4 . A feed shaft 112 supported by the rear wall 106 so as to be parallel with the guide rails 107 fitted through a block 111 integrally formed with the lower support plate 110. As shown in Fig. 2, the feed shaft 112 has both ends rotatably supported by bearings 113 and has a pulley 114, secured to one end thereof, connected to an output pulley 116 of a longitudinal movement motor 115 through a belt 117 so that the feed shaft is rotated by the motor 115. In addition, the block 111 incorporates a mechanism for axially (longitudinally) moving the block in co-operation with the feed shaft 12. When the feed shaft is rotated

by the mechanism, the block 111, and thus the upper and lower support plate 109, 110, can be integrally moved in the longitudinal direction in accordance with the sense of the feed shaft rotation.

5 A projection 119 of a substantially L-shaped movable plate 118 is fitted on each of the guide rods 108 provided between the upper and lower support plates 109, 110 so that the movable plate 118 can vertically move with respect to the support plates 109, 110. Moreover, a
10 block plate 120 projects from a substantially central portion of the rear surface of the movable plate 118 and engages the thread of a worm rod 121 vertically and rotatably supported between the support plates 109, 110 so that the movable plate 118 can be vertically moved
15 with respect to the support plates 109, 110 by the rotation of the worm rod 121. The worm rod 121 has a pulley 122 provided integrally with the lower end thereof, and a belt 125 connects the pulley 122 to a pulley 124 of a motor 123 secured to the support plate
20 110, thereby driving the worm rod.

On the other hand, a sliding plate 127, capable of moving in the direction (referred to as "lateral direction", hereinafter) perpendicular to the longitudinal direction along steps 126 provided at the
25 front and the rear respectively, is mounted on the

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horizontal part of the movable plate 118. The sliding plate 127 has a vertical member 128 integrally formed at one end of the upper surface thereof. The vertical member 128 is threaded with a lateral regulation bolt 130 rotatably supported by a fixed vertical member 129 which is vertically disposed at the left end of the movable plate 118 so as to face to the vertical member 128. The bolt 130 is adapted to move the sliding plate 127 laterally, thereby to regulate the position of the sliding plate 127 with respect to the movable plate 118. The bolt 130 has a knob 131 disposed at its end. Manually rotating the knob 131 permits the bolt 130 to revolve on its axis, thereby allowing the sliding plate 127 to move laterally on the movable plate 118.

On the sliding plate 127, a vertically swinging plate 132 adapted to support a fork, described hereinafter in detail, is supported by bearings 133 and a shaft (not shown) at one end 132a thereof. Moreover, an eccentric cam 134 in the form of a short cylinder is horizontally disposed at a position corresponding to a substantially central portion of the vertically swinging plate 132 and supported by bearings 135 so that the vertically swinging plate 132 can rotate in the vertical direction. In addition, the eccentric cam has a worm wheel 136 secured to one end thereof. The worm wheel 136

is engaged with a rotating worm 138 of a swing motor 137 secured on the sliding plate 127 so that the eccentric cam 134 can be revolved on its axis by the motor 137.

A fork holder 139 having a substantial V-shaped section is secured to the vertically swinging plate 132 by means of a bolt 140, at an end portion thereof, and on the holder 139 a fork 141 is substantially horizontally supported in the longitudinal direction by means of two belts 142. The fork 141 is formed into a tubular shape using quartz material, and an upper end portion 141a thereof is formed by cutting away the upper part of the tube, so as to be able to mount a plurality of wafer jigs 103 in a row, as shown in Fig. 2. Accordingly, as shown in Fig. 5, since the central part of the vertically swinging plate 132 is supported by the circumferential surface of the eccentric cam 134, the end 141a of the fork 141, together with the vertical swinging plate 132 and the fork holder 139, can be swung vertically when the eccentric cam 134 is rotated as shown by chain lines of the figure. Moreover, when the bolt 140 is loosened, the fork end 141a can be swung in the horizontally lateral direction with respect to the vertically swinging plate 132.

Further, an inner cap 143 and an outer cap 144 can be set inside and outside the substantially central

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portion of the fork 141 respectively, as shown in Fig. 6 (A), Fig. 6 (B) and Fig. 6 (C). These caps 143, 144 have outer casings made of quartz glass and the insides filled with quartz wool and are provided with handles 143a, 144a and air vents 143b, 144b respectively. The inner cap 143 is formed as a short cylinder and can be loaded in the fork 141, while the outer cap 144 is formed into a thick crescent-shaped disc having a semi-elliptical reentrant portion 144c and can be mounted on the upper part of the fork. When the fork 141 thus fitted with the inner and outer caps 143, 144 is entered into the process tube 102 made of quartz, as described hereinafter, these caps 143, 144 can close off the entry end of the quartz process tube 102.

The function of the soft landing loader having the above-mentioned arrangement will be described hereinafter.

Fig. 7 illustrates a process for setting the wafer jigs 103 in the quartz process tube 102. On the end 141a of the fork 141 prepared as shown in Fig. 7 (A), a plurality of wafer jigs 103 are mounted as shown in Fig. 7 (B). In this case, since the fork end is downwardly deformed by the weight of the wafer jigs, the vertical movement motor 123 is driven to rotate the worm rod 121 in order to move upwardly the movable plate 118, thereby

to move upwardly the whole of the fork 141 as shown in Fig. 7 (C). Moreover, the vertical swing motor 137 is driven to rotate the eccentric cam 134, thereby allowing the fork end 141a to swing upwardly as shown in Fig. 5..

5 Consequently, the position of the fork end is corrected so as to be substantially horizontal as shown in Fig. 7 (D). Then, when the longitudinal movement motor 115 is driven to rotate the feed shaft 112, the block 111 actuates the support plates 109, 110 to advance towards

10 the right of the figure, so that the fork 141 enters into the quartz process tube 102 and stops at a given position as shown by solid lines in Fig. 7 (E). Hereupon, reversing the vertical movement motor 123 permits the whole of the fork 141 to move downwardly as shown by

15 chain lines in Fig. 7 (E), and the lower ends of the wafer jigs 103 are brought into contact with the inner bottom surface of the quartz process tube 102 at a given position of lowering. In this connection, a larger scale illustration of the position reached is shown in Fig. 8

20 Thereafter, when the vertical movement motor 137 is reversed in order to swing the fork end 141a downwardly, the downwardly moved end is released from supporting the wafer jigs 103 as shown in Fig. 7 (F). Accordingly, when the longitudinal movement motor 115 is then reversed in

25 order to allow the fork 141 to move towards the left of

the figure and withdrawn from the quartz process tube 102 and at the same time, the vertical movement motor 123 is rotated so as to move the fork 141 upwardly, the fork is returned to its initial position as shown by solid lines or dash and two-dotted lines of the Fig. 7 (G).

According to the process described above, the wafer jigs 103 can be entered into the quartz process tube 102 without the loader contacting with the inside thereof and gently mounted inside the process tube.

Fig. 9 illustrates a process for unloading the wafer jigs from the quartz process tube, when their wafers have completed a thermal treatment. The fork 141 is advanced from the position of readiness shown in Fig. 9 (A) into the quartz process tube 102 by operating the longitudinal movement motor 115, and the fork end 141a is advanced under the wafer jigs 103 as shown in Fig. 9 (B). Then, the vertical movement motor 123 is operated in order to move the whole of the fork vertically, thereby allowing the fork end to scoop up the wafer jigs 103 as shown in Fig. 9 (C). On doing this, the end 141a is downwardly deformed by the weight of the wafer jigs 103. Therefore, operating the vertical swing motor 137 permits the fork end to be swung upwardly, so that the fork supports the wafer jigs with the end kept substantially horizontal as shown in Fig. 9 (D). Thereafter, reversing

the longitudinal movement motor 115 permits the fork to retreat out of the quartz process tube 102 as shown by solid lines of Fig. 9 (E) and at substantially the same time, the vertical movement motor 123 is driven in order to move the whole of the fork downwardly as shown by chain lines of the figure, and moreover the vertical swing motor 137 is driven in order to swing the fork end 141a downwardly to its initial state as shown in Fig. 9 (F). Accordingly, when the operator removes the wafer jigs 103 from the fork under this state, the fork is returned to its initial state as shown in Fig. 9 (G). The wafer jigs 103 are thus also unloaded without the fork contacting the quartz process tube in the wafer jig unloading process.

Therefore, there is no possibility of generation of dust particles due to wear between the wafer jigs 103 and the inner surface of the quartz process tube 102, since the wafer jigs 103 are moved along the quartz process tube 102 without contacting with the inner surface thereof when the wafer jigs are loaded and unloaded in the above-mentioned processes. Moreover, since the fork 141 can not only move vertically and longitudinally but also swing the end 141a vertically, even when the fork is deformed due to the weight of the wafer jigs, it can support them in a substantially horizontal state, so that

there is little chance that the wafer jigs will fall from the fork. In this case, there is also the advantage that even when the fork is moved downwardly, the fork and the quartz process tube will not foul each other, because if the fork end is deformed downwardly, this is corrected upwardly.

An example of the use of this soft landing loader with the above-mentioned basic functions will be described hereinafter. First, in this thermal treatment apparatus, the relative positions of the fork with respect to the quartz process tube 102 are separately shown in Fig. 10 (A), Fig. 10 (B) and Fig. 10 (C), and the respective positions are referred to below as P_1 , P_2 and P_3 : at P_1 , the fork 141 is completely withdrawn from the quartz process tube 102, at P_2 , the fork end 141a is positioned in a soaking part 102a of the quartz process tube 102, namely the wafer jigs are positioned within the soaking part 102a; and at P_3 , although having been withdrawn from the soaking part 102a of the quartz process tube 102, the fork end 141a is still within the quartz process tube 102 and at this time, the above-mentioned inner and outer caps 143, 144 are at the end of the quartz process tube where they close off the entry opening.

After these positions, P_1 , P_2 and P_3 , are set, by

interactive means between the furnace control system and the loader control system sequential control is performed in modes such as shown in Fig. 11(A), Fig. 11(B) and Fig. 11(C), thereby to make it possible to effect control

5 corresponding to various treatments. Namely, MODE A and MODE B shown in Fig. 11 are employed when treatment temperatures are relatively high, e.g., in case of diffusion treatment, thermal oxidation treatment or CVD treatment for wafers. In MODE A, after the fork is moved

10 to P_2 in order to set the wafer jigs within the soaking part in a step S_1 shown in Fig. 11, the fork is retreated to P_3 in a step S_2 . Then, with the quartz process tube closed by means of the inner and outer caps, a thermal treatment such as diffusion, thermal oxidation, CVD,

15 annealing or the like is conducted. Since the fork end is near the end of the quartz process tube at this time, it is hardly affected by heat. Although in thermal treatments it may be possible that the quartz wafer jigs fuse with the quartz process tube due to the treatment

20 heat and the contact positions (lower ends) thereof, and adhere to the inner surface of the tube, this is prevented by means of a step S_3 in which the fork is operated according to a timer control. In other words, by the operation of an interval timer, the fork advances

25 to P_2 from P_3 at suitable intervals, and at P_2 , the fork

end is upwardly swung and positioned there for a short period. Thereby, the wafer jigs are lifted during that period, so that they are separated from the inner surface of the quartz process tube to prevent them from fusing with the inner surface thereof. On completion of the operation, the fork returns to P_3 again. The operation is repeated at suitable intervals during the treatment to make it possible to reliably prevent the fusing of the wafer jigs with the process tube. After the thermal treatment is completed, the fork end enters under the wafer jigs again in a step S_4 , and the wafer jigs are unloaded from the quartz process tube at a step S_5 . Accordingly, even in high-temperature treatments, it is possible to prevent the fusing of the wafer jigs as well as the thermal deformation of the fork, so that satisfactory thermal treatments can be completed.

In MODE B, as shown by steps S_6 , S_7 illustrated in Fig. 11, after the wafer jigs are entered into the quartz process tube the fork is retreated to P_1 , i.e., the fork is completely drawn out of the quartz process tube, and then a thermal treatment is conducted. On completion of the thermal treatment, the fork is inserted and withdrawn again in steps S_8 , S_9 to make it possible to unload the wafer jigs from the quartz process tube. The MODE B is appropriate for thermal treatments at extremely high

temperatures, and it is more effective if an automatic cap for the quartz process tube is used at the same time.

MODE C is appropriate for treatments at relatively low temperatures, such as annealing treatment. In the
5 MODE C in a step S_{10} shown in Fig.11 , the fork is advance to P_2 in order to enter the wafer jigs within the soaking part of the quartz process tube, and with this condition maintained, a thermal treatment is conducted. On completion of the thermal treatment, the wafer jigs
10 are unloaded from the quartz process tube in a step S_{11} . Since the treatment temperature is low, needless to say, there is no possibility of any thermal deformation of the fork.

It suffices that the above-mentioned modes are
15 previously programmed and fed to a microcomputer so that a desired mode can be obtained by depressing a selection switch. In case of arranging the apparatus so as to be an all-purpose machine, the arrangement is such that the fork can be manually operated, e.g., it suffices to
20 arrange the switch panel of the control panel 101A such as shown in Fig.12 . In such an apparatus, an operation switch group 145 in the lower part of the panel for controlling the operation of the fork can be used in semiautomatic and manual modes. In the manual mode, the
25 fork is operated only while a switch of the group is

being depressed, while in the semiautomatic mode, once the switch is depressed the fork is automatically moved and stopped at the subsequent position. In addition, the above-mentioned modes A, B and C, are made available through selection of switches 146 corresponding to A, B and C respectively.

The function of each of switches of the control panel shown in Fig. 12 is as follows.

Depressing the POWER switch permits all power sources of the soft landing loader to be turned ON. When MANUAL is turned ON, the manual mode is obtained, and each of switches 145 are made effective, so that while each is ON, the operation mode corresponding to that switch is actuated. When SEMIAUTO is turned ON, each of switches 145 are made effective such that when each is depressed (turned ON), the soft landing loader automatically moves to the subsequent position in the corresponding direction. When LOCAL is turned ON, the mode is changed into LOCAL MODE. When STOP is turned ON, the motion of the soft landing loader can be temporarily stopped.

Figs. 13 to 16 show the sequences of the soft landing loader respectively: Fig. 13, shows the sequence in LOCAL MODE: Fig. 14 shows the sequence in the MODE A shown in Fig. 11; Fig. 15 shows the sequence in the MODE

B shown in Fig. 11 ; and Fig. 16 shows the sequence in the
MODE C shown in Fig. 11 .

The present invention is not limited to the above-
mentioned preferred embodiment, and in practice devices
5 for moving the fork longitudinally and vertically and for
swinging the same vertically can take many forms.

As will be fully understood from the foregoing
description, the thermal treatment apparatus according to
the present invention can prevent generation of dust
10 particles by maintaining the inner surface of the process
tube and the wafer jigs or the like out of contact with
each other in loading and unloading of the wafer jigs,
since the fork for transferring the wafer jigs is adapted
to be able to move at least vertically and longitudinally
15 with respect to the thermal treatment furnace, and the
wafer jigs can be moved vertically by swinging the fork
end. Moreover, since the wafer jigs can be lifted
intermittently by putting the fork in and out during a
thermal treatment, it is possible to prevent the fusing
20 of the wafer jigs with the process tube due to heat as
well as to prevent the thermal deformation of the fork,
thereby to make it possible to conduct thermal treatments
very satisfactorily under high-temperature conditions.

Attention is drawn to our application No.
84.24276 (2 148 471) which has been divided from this
application.



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CLAIMS

1. A thermal treatment apparatus comprising, a horizontally extending furnace tube for subjecting wafers to a thermal treatment, said furnace tube having an opening;

5 a loader disposed on the opening side of said furnace tube, for carrying a plurality of wafer jigs in the horizontal direction from outside of said furnace tube to inside of said furnace tube, wherein said loader includes:

a fork extending in the horizontal direction and having two end portions, with one end portion adapted to have said plurality of wafer jigs placed thereon;

15 first means for supporting the other end portion of said fork and for moving said fork in the horizontal direction;

said first means having second means for vertically moving said fork with respect to said furnace tube and having third means for adjusting a gradient of said fork with respect to said horizontally extending furnace tube;

2. A thermal treatment apparatus according to claim 1, wherein said third means is positioned adjacent the other end portion of said fork:

25 3. A thermal treatment apparatus according to claim 1 or claim 2 wherein said third means is arranged to cause said one end portion to swing vertically.



(13)

4. A thermal treatment apparatus according to Claim 1, 2 or 3 wherein said furnace tube is of quartz.

5 5. A thermal treatment apparatus according to Claim 1, 2 or 3 wherein said fork is of quartz and is of a pipe shape.

6. A thermal treatment apparatus according to any one of the preceding claims wherein said first means has a part adapted to move along a pair of guide rails.

10 7. A thermal treatment apparatus according to any one of the preceding claims wherein said second means and third means have respective motors.

8. A thermal treatment apparatus according to Claim 5, wherein said fork has an outer and an inner cap adapted to cooperate in sealing off the opening of the furnace tube, said outer and inner caps being of quartz.

15 9. A thermal treatment apparatus constructed and arranged for use and operation substantially as described herein with reference to the accompanying drawings.

20 10. A method of subjecting wafers to a thermal treatment substantially as described herein with reference to the accompanying drawings.

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