

## **WAFER BOAT AND FURNACE TUBE APPARATUS**

### **FIELD OF THE INVENTION**

The present invention relates to the technical field of semiconductor equipment, and specifically relates to a wafer boat and a furnace tube apparatus.

### **BACKGROUND**

As shown in FIG. 14, a heating device 5000' of a furnace tube apparatus is disposed on the outer circumference of a liner tube 2000'. Heat transfers from the outer circumference of the liner tube 2000' toward the interior of the liner tube 2000'. Under medium and low temperature process conditions, heat loss occurs during heat transmission, which leads to uneven temperature distribution on substrates W inside the liner tube 2000'. That is, the temperature of outer peripheral regions of the substrates W is higher than the temperature of central regions of the substrates W. Uneven temperature distribution on the substrates W will result in non-uniform film thickness after film formation on the substrates W.

### **SUMMARY**

The present invention provides a wafer boat and a furnace tube apparatus, aiming to overcome the defect in the prior art that the temperature of outer peripheral regions of substrates in a furnace tube apparatus is higher than the temperature of central regions of the substrates, which causes non-uniform film thickness after film formation.

The present invention solves the above technical problem through the following technical solutions.

The present invention provides a wafer boat, for carrying multiple layers of substrates spaced apart along a vertical direction in a furnace tube apparatus, comprising:

a plurality of heaters, spaced apart along the vertical direction;

wherein the heaters are configured to heat central regions of the substrates when

the wafer boat carries the substrates.

The present invention provides a wafer boat, for carrying multiple layers of substrates spaced apart along a vertical direction in a furnace tube apparatus, comprising:

multiple layers of gas supply components, spaced apart along the vertical direction, and respectively disposed above and/or below corresponding substrates;

a gas supply pipeline, in communication with the multiple layers of gas supply components, for supplying gas to the multiple layers of gas supply components.

The present invention provides a furnace tube apparatus comprising a process tube and the above wafer boat, wherein the wafer boat is disposed inside the process tube, multiple layers of exhaust ports are arranged on a side wall of the process tube along a vertical direction of the process tube, and each layer of exhaust ports corresponds to at least one layer of the gas supply components.

The positive and progressive effects of the present invention are as follows:

1. By arranging a plurality of heaters to heat central regions of substrates, the wafer boat of the present invention can raise the temperature of the central regions of the substrates, thereby improving the uniformity of film thickness after film formation.

2. Gas supply components are disposed above and/or below each layer of substrates, which enables more uniform and sufficient gas supply, achieves better uniformity of gas atmosphere around different substrates, and helps improve film uniformity after film formation within each substrate surface and among different substrates.

3. The furnace tube apparatus provided by the present invention realizes a more uniform gas supply among substrates of different layers. Multiple layers of exhaust ports are arranged inside the process tube, each layer of exhaust ports corresponds to the gas supply component of the corresponding layer, so that the exhaust is more uniform, and further, the thin film uniformity deposited on each layer of substrates inside the process tube can be improved.

## BRIEF DESCRIPTION OF THE DRAWINGS

The features and performance of the present application will be further described by the following embodiments and accompanying drawings of the embodiments.

FIG. 1 is a schematic structural view illustrating a first layout of heaters in the wafer boat according to Embodiment 1 of the present invention;

FIG. 2 is a schematic structural view illustrating the installation structure of the heater in the wafer boat according to Embodiment 1 of the present invention;

FIG. 3 is a schematic structural view illustrating a second layout of heaters in the wafer boat according to Embodiment 1 of the present invention;

FIG. 4 is a schematic structural view illustrating a third layout of heaters in the wafer boat according to Embodiment 2 of the present invention;

FIG. 5A is a schematic structural view illustrating a fourth layout of heaters in the wafer boat according to Embodiment 2 of the present invention;

FIG. 5B is a schematic structural view illustrating a fifth layout of heaters in the wafer boat according to Embodiment 2 of the present invention;

FIG. 6 is a schematic structural view illustrating a sixth layout of heaters in the wafer boat according to Embodiment 2 of the present invention;

FIG. 7A is a schematic structural view illustrating the heater layout of the wafer boat according to Embodiment 3 of the present invention;

FIG. 7B is a schematic structural view illustrating the heater layout of the wafer boat according to Embodiment 4 of the present invention;

FIG. 8 is a schematic structural view illustrating the layout of gas supply components in the wafer boat according to Embodiment 5 of the present invention;

FIG. 9 is a schematic structural view of the gas supply component in the wafer boat according to Embodiment 5 of the present invention;

FIG. 10 is a schematic structural view illustrating the layout of heaters and gas supply components in the wafer boat according to Embodiment 6 of the present invention;

FIG. 11 is a schematic structural view illustrating the layout of heaters and gas supply components in the wafer boat according to Embodiment 7 of the present invention;

FIG. 12 is a schematic structural view of the furnace tube apparatus according to Embodiment 8 of the present invention;

FIG. 13 is a cross-sectional structural view taken at position B of FIG. 12 according to the present invention;

FIG. 14 is a schematic structural view of a furnace tube apparatus according to the prior art.

## PREFERRED EMBODIMENTS OF THE APPLICATION

The present invention will be further described below through embodiments, but this does not limit the present invention to the scope of these embodiments.

### Embodiment 1

As shown in FIG. 1, the present embodiment provides a wafer boat for carrying substrates W in a furnace tube apparatus, and the wafer boat can heat central regions of the substrates W in a non-contact manner, so as to balance temperature differences between central regions and outer peripheral regions of the substrates W. The wafer boat comprises a carrying main body 100 and heaters 200. The carrying main body 100 is provided with multiple layers of carrying members 110 for carrying the substrates W, the multiple layers of carrying members 110 are spaced apart along a vertical direction of the carrying main body 100, and each layer of carrying members 110 carries one substrate W. The heaters 200 are spaced apart along the vertical direction of the carrying main body 100, the heaters 200 are disposed above and below the substrates W, and the heaters 200 are configured to heat central regions of the substrates W when the carrying members 110 carry the substrates W.

In the example shown in FIG. 1, the heaters 200 are disposed above and below the carrying members 110, one heater 200 is disposed every other layer of the carrying members 110, and the heater 200 corresponds to the central region of the substrate W, so that the heater 200 can heat the central region of the substrate W at each layer. A heating device of the current furnace tube apparatus is disposed at the periphery of the furnace tube apparatus, and heat transfers from the periphery toward the interior of the furnace tube apparatus. During film-forming processes, especially film-forming processes carried out at medium and low temperatures below 500 degrees Celsius, the temperature at the central region of each substrate W is lower than the temperature at the outer peripheral region of the substrate W, resulting in uneven temperature distribution within the substrate W, which leads to non-uniform film thickness after film formation within the substrate W. The wafer boat of the present embodiment can increase the temperature of the central region of each substrate W, the temperature of each heater 200 can be adjusted by regulating the output power of the heater 200, so as to balance the temperature difference between the central region and the outer peripheral region of each substrate W and improve the uniformity of film thickness after film formation.

In the present embodiment, each heater 200 adopts a heating sheet for heating, the heating surface of the heater 200 corresponds to the central region of the substrate W, and each heater 200 mainly heats the central region of the substrate W by means of thermal convection. In addition, electric heating wires may also be adopted for heating.

As shown in FIG.1 and FIG. 2, the carrying main body 100 includes carrying members 110 and carrying columns 120, the carrying members 110 are connected to the carrying columns 120 and used for carrying the substrates W. Each heater 200 is connected to the carrying column 120 through a carrying plate 230. In other embodiments, the fixing mode of each heater 200 is not limited to this mode; the heater 200 may also be fixed on the carrying column 120 or the carrying member 110 through connecting rods.

In the present embodiment, a power supply line 240 of the heater 200 is fixed on the outer circumferential surface of the carrying column 120. Preferably, the power supply line 240 is made of high-temperature-resistant materials.

In other embodiments, a hollow carrying column may be adopted, and the power supply line 240 passes through the interior of the carrying column, so that the line layout is more compact.

As shown in FIG. 1, the heaters 200 are disposed above and below the substrates W, that is, the heaters 200 are arranged both above and below each layer of substrates W. Each layer of substrates W is provided with two heaters 200, the two heaters 200 respectively heat the upper surface and the lower surface of the substrate W, which can supply more heat to the central region of the substrate W and achieve a better heating effect.

The arrangement of the heaters 200 inside the wafer boat is not limited to the mode where the heaters 200 are spaced apart by one layer of substrates W, as shown in FIG.1. The present embodiment also provides another spaced arrangement. As shown in FIG. 3, a heater 200 positioned between two layers of substrates W can heat both layers of substrates W simultaneously. Therefore, the heaters 200 can be arranged at intervals of two layers of substrates W, i.e., at intervals of two carrying members 110. While ensuring that the central region of the substrate W at each layer can be heated, the required number of the heaters 200 is greatly reduced, which helps lower manufacturing costs.

It should be noted that the examples shown in FIG. 1 and FIG. 3 shall not limit the number of substrate layers spaced between adjacent heaters. For example, in some embodiments, one heater may be disposed at intervals of three or more layers of substrates, and adjacent heaters jointly heat central regions of multiple layers of substrates located between the adjacent heaters.

In the present embodiment, the wafer boat further comprises a rotation device and an electric brush. The rotation device (not shown in the drawings) is disposed at the bottom of the wafer boat and configured to drive the wafer boat to rotate. The power supply line 240 of each heater 200 is connected to the power source of the heater 200 through the electric brush.

In the present embodiment, the wafer boat further comprises a heat insulation sheet 300 disposed at the bottommost end of the wafer boat for heat preservation and

reducing heat loss from the bottom of the wafer boat.

In the present embodiment, film layers will be deposited on the heaters 200 during service. Cleaning gas can be introduced periodically to clean the heaters 200, or other cleaning modes can be adopted for cleaning.

## Embodiment 2

The solution of the present embodiment is substantially the same as the solution of Embodiment 1, and the difference lies in that the heaters 200 of the present embodiment adopt radiant heating, such as infrared radiant heaters. Radiant heating has the following advantages: 1. Radiant heating has a high electrothermal efficiency; 2. The heating range is easier to control, so that the central regions of the substrates W can be heated more accurately; 3. Heat can penetrate into heated objects without generating intense heat exchange on the surfaces of the substrates W, which prevents the surfaces of the substrates W from being damaged due to instantaneous overheating.

The arrangement of the heaters 200 is associated with the heating direction of the heaters 200.

As shown in FIG. 4, each heater 200 heats the upper surface of a corresponding substrate W in a top-down manner, and the heater 200 is disposed above the substrate W of the corresponding layer.

As shown in FIG. 5A, each heater 200 heats the lower surface of a corresponding substrate W in a bottom-up manner, and the heater 200 is disposed below the substrate W of the corresponding layer.

As shown in FIG. 6, each heater 200 can heat in two directions at the same time. Therefore, the heater 200 can be arranged at intervals of two layers of the substrates W, and the heater 200 disposed between two adjacent layers of the substrates W can heat the two layers of the substrates W simultaneously, so as to reduce the number of the heaters 200.

As shown in FIG. 5B, when each heater 200 heats the lower surface of a corresponding substrate W, a partition plate 130 is disposed below the substrate W to

prevent impurities falling from the lower surface of the upper substrate W from dropping onto the lower substrate W.

### Embodiment 3

The solution of the present embodiment is substantially the same as the embodiment of Embodiment 1, and the difference is shown in FIG 7A: In the present embodiment, the heaters 200 are connected to the carrying members 110 along the horizontal direction A. Specifically, each heater 200 is disposed at the middle part of the carrying member 110, the carrying member 110 fixes the heater 200, and the carrying member 110 is connected to the carrying columns 120. When each substrate W is carried on the carrying member 110, the heater 200 is located at the middle part of the carrying member 110 and corresponds to the central region of the substrate W. When each substrate W is placed on the carrying member 110, the heater 200 corresponds to the central region of the substrate W and can heat the central region of the substrate W accurately.

In the present embodiment, the upper surface of each heater 200 is flush with the upper surface of the corresponding carrying member 110, the central region of each substrate W is in contact with the upper surface of the heater 200, and heating is mainly realized by thermal conduction.

In some embodiments, if thin films need to be deposited on the lower surfaces of the substrates W, the heaters 200 may also be disposed above the substrates W in a contact manner.

In other embodiments, the upper surface of each heater 200 may be lower than the upper surface of the corresponding carrying member 110; when the substrate W is placed on the carrying member 110, the central region of the substrate W does not contact the heater 200, and the heater 200 mainly heats the central region of the substrate W by convection or radiation.

### Embodiment 4

The solution of the present embodiment is substantially the same as the solution

of Embodiment 3, and the difference is shown in FIG. 7B: The wafer boat of the present embodiment is not provided with carrying members. Each heater 200 is disposed below the central region of the corresponding substrate W in a contact manner, and the heater 200 not only heats the central region of the substrate W but also carries the substrate W. In the present embodiment, each heater 200 is fixed to the middle part of the wafer boat through a fixing member 210, each fixing member 210 is connected to the carrying columns 120, and the fixing members 210 may be connecting rods.

#### Embodiment 5

As shown in FIG. 8 and FIG 9, the present embodiment provides a wafer boat capable of realizing a more uniform and sufficient gas supply, and the wafer boat comprises the carrying main body 100, the multiple layers of gas supply components 400, and a gas supply pipeline. The carrying main body 100 is provided with multiple layers of carrying members 110 for carrying the substrates W, and the multiple layers of carrying members 110 are spaced apart along the vertical direction of the carrying main body 100. The multiple layers of gas supply components 400 are spaced apart along the vertical direction of the carrying main body 100, and are disposed above the substrates W of corresponding layers. The gas supply pipeline is in communication with the multiple layers of gas supply components 400 and are used for supplying gas to the multiple layers of gas supply components 400, respectively.

By arranging the gas supply components 400 above the substrates W of the corresponding layers, the gas supply becomes more uniform and sufficient, and the uniformity of the gas atmosphere around the substrates W of different layers is improved, which helps improve the uniformity of the thin films formed on the substrates W of different layers. By adopting the wafer boat of the present embodiment, gas distribution inside the wafer boat is more uniform, so there is no need to arrange an additional rotation device to rotate the wafer boat for improving gas distribution uniformity.

In other embodiments, the layout of the gas supply components 400 is not limited to this mode. If thin films need to be deposited on the lower surfaces of the substrates W in certain processes, the gas supply components 400 may also be disposed below the substrates W of the corresponding layers.

In some embodiments, gas supply components 400 may be arranged both above and below each layer of substrates W to ensure good film uniformity on both upper and lower surfaces of each substrate.

In the present embodiment, the gas supply pipeline includes a main pipeline 511 and a plurality of branch pipelines 512, the gas supply component 400 at each layer is connected to the main pipeline 511 through a corresponding branch pipeline 512. The main pipeline 511 may be disposed on the outer periphery of the carrying column 120 of the carrying main body 100.

In some embodiments, the carrying columns 120 of the carrying main body 100 may be of hollow structures, and the main pipeline 511 may be disposed inside the hollow structure of the carrying columns 120. In addition, the main pipeline 511 may be omitted, and gas supply can be realized by means of the hollow carrying columns.

A regulating valve 520 is disposed on the branch pipeline 512 corresponding to the gas supply component 400 at each layer, and the regulating valve 520 is used for adjusting the gas supply flow rate of the corresponding branch pipeline 512. The gas supply flow rate of the gas supply component 400 at each layer can be controlled through the regulating valve 520, so as to balance differences in gas supply flow rate among different layers, realize more uniform gas supply volume among different layers, and help improve the uniformity of thin film deposition on the substrates W of different layers.

In the present embodiment, each gas supply component 400 corresponds to the central region of the substrate along the horizontal direction A, and supplies gas toward the substrate W and outward to the periphery in a horizontal direction A, i.e., the direction parallel to the substrate.

Specifically, as shown in FIG. 8 and FIG. 9, each gas supply component 400 includes a hollow cavity 430 provided with a gas inlet 440 connected to the gas supply pipeline, namely the branch pipeline 512. A plurality of first gas supply holes 410 are spaced apart on the surface of the hollow cavity 430 facing the substrates W, and a plurality of second gas supply holes 420 are spaced apart on the outer circumferential surface of the hollow cavity 430. The first gas supply holes 410 supply gas toward the

substrate W; the first gas supply holes 410 may supply gas perpendicularly toward the substrate W or supply gas at a certain inclination angle relative to the substrate W. The second gas supply holes 420 supply gas outward along the horizontal direction A. The arrangement of the first gas supply holes 410 and the second gas supply holes 420 improves the gas diffusion effect of each gas supply component 400, enables process gas to be distributed more uniformly in all regions of each substrate, and helps improve the in-plane uniformity of the substrate.

In other embodiments, only the first gas supply holes 410 or only the second gas supply holes 420 may be arranged.

In some embodiments, the structure of the gas supply components 400 is not limited to the above mode, gas may also be supplied directly through the gas inlet pipes, or other gas supply structures may be adopted.

#### Embodiment 6

The solution of the present embodiment is substantially the same as the solution of Embodiment 5, and the difference lies in that the wafer boat of the present embodiment further comprises the plurality of heaters 200 spaced apart along the vertical direction of the carrying main body 100 and disposed below the substrates W of the corresponding layers, respectively, as shown in FIG. 10. Besides, the heaters 200 are configured to heat the central regions of the substrates W when the substrates W are carried on the carrying members 110.

#### Embodiment 7

The present embodiment provides a wafer boat whose structure is substantially the same as the wafer boat of Embodiment 6, and the difference lies in that the heaters 200 in the present embodiment adopt the structure and layout described in Embodiment 3. Specifically, as shown in FIG. 11, the multiple layers of gas supply components 400 of the wafer boat are spaced apart along the vertical direction of the carrying main body 100.

In some embodiments, the layout of the heaters may be adaptively modified

according to actual requirements, and reference may be made to the layout of the heaters 200 described in the above embodiments.

#### Embodiment 8

As shown in FIG. 12 and FIG. 13, the present embodiment provides a furnace tube apparatus, which comprises a process tube 2000 and the wafer boat of any of the above embodiments (taking the wafer boat of Embodiment 5 as an example). A wafer boat 1000 is disposed inside the process tube 2000, the carrying members 110 are spaced apart along the vertical direction L of the process tube 2000, multiple layers of exhaust ports 2100 are arranged on a side wall of the process tube 2000 along the vertical direction L, and each layer of exhaust ports 2100 corresponds to one layer of gas supply components 400.

The multiple layers of gas supply components 400 arranged in the wafer boat enable a more uniform gas supply among the substrates W of different layers. The multiple layers of exhaust ports 2100 are arranged inside the process tube 2000, each layer of the exhaust ports 2100 corresponds to the gas supply component 400 of the corresponding layer, so that the exhaust is more uniform, and further, the uniformity of thin films deposited on each layer of the substrates W inside the process tube 2000 can be improved.

In other embodiments, each layer of the exhaust ports 2100 arranged on the process tube 2000 may correspond to the multiple layers of gas supply components 400, so that the number of layers of the exhaust ports 2100 can be reduced.

As shown in FIG. 13, in this embodiment, each layer of the exhaust ports 2100 includes a plurality of openings 2110 spaced circumferentially. Each gas supply component 400 is provided with a plurality of second gas supply holes 420 spaced circumferentially, and the plurality of second gas supply holes 420 correspond to the plurality of openings 2110 at the same layer. In some embodiments, the openings 2110 and the second gas supply holes 420 may be arranged in a staggered manner along the circumferential direction of the same layer.

In the present embodiment, the furnace tube apparatus further comprises a liner

tube 3000, sleeved on the outer side of the process tube 2000; and a heating assembly 5000, disposed on the outer side of the liner tube 3000, and configured to heat the liner tube 3000.

Further, the furnace tube apparatus further comprises a gas pump 4000. The liner tube 3000 is provided with an extraction port, and the gas pump 4000 is disposed at the extraction port. Excess gas can be extracted through the gas pump 4000.

In other embodiments, a plurality of extraction ports are arranged on the liner tube 3000 spaced circumferentially, and a gas pump 4000 is disposed at each extraction port, which helps improve exhaust efficiency and the uniformity of gas distribution.

In this embodiment, film layers will be deposited on the gas supply components 400 during service. Cleaning gas can be introduced periodically to clean the gas supply components 400, or other cleaning modes can be adopted for cleaning.

Although specific embodiments of the present invention have been described above, those skilled in the art shall understand that the above description is merely illustrative. The protection scope of the present invention is defined by the appended claims. Those skilled in the art can make various variations or modifications to these embodiments without departing from the principle and essence of the present invention, and all such variations and modifications shall fall within the protection scope of the present invention. In addition, certain features, structures, or characteristics of one or more embodiments of the present application can be appropriately combined with each other.

What is claimed is:

1. A wafer boat, for carrying multiple layers of substrates spaced apart along a vertical direction in a furnace tube apparatus, comprising:

a plurality of heaters, spaced apart along the vertical direction;

wherein the heaters are configured to heat central regions of the substrates when the wafer boat carries the substrates.

2. The wafer boat according to claim 1, wherein the heaters are disposed opposite the central regions of the substrates, and the heaters are arranged above or below the substrates adjacent thereto in a contact manner or a non-contact manner.

3. The wafer boat according to claim 1, wherein one heater is provided every at least one substrate layer.

4. The wafer boat according to claim 1, wherein the wafer boat further comprises a carrying main body, the carrying main body includes multiple layers of carrying members for carrying the multiple layers of substrates, and the multiple layers of carrying members are spaced apart along the vertical direction of the carrying main body.

5. The wafer boat according to claim 1, wherein the heaters adopt radiant heating.

6. The wafer boat according to claim 1, wherein the wafer boat further comprises a rotation device and an electric brush, the rotation device is disposed at the bottom of the wafer boat and configured to drive the wafer boat to rotate, and a power supply line of the heaters is connected to the power source of the heaters through the electric brush.

7. A furnace tube apparatus, comprising the wafer boat according to any one of claims 1 to 6.

8. A wafer boat, for carrying multiple layers of substrates spaced apart along a vertical direction in a furnace tube apparatus, comprising:

multiple layers of gas supply components, spaced apart along the vertical direction, and respectively disposed above and/or below the corresponding substrates;

a gas supply pipeline, in communication with the multiple layers of gas supply components, and configured to supply gas to the multiple layers of gas supply components.

9. The wafer boat according to claim 8, wherein the gas supply components correspond to the central regions of the substrates.

10. The wafer boat according to claim 8 or claim 9, wherein the gas supply components supply gas toward the substrates, and/or the gas supply components supply gas outward in a direction parallel to the substrates.

11. The wafer boat according to claim 10, wherein each of the gas supply components includes a hollow cavity provided with a gas inlet connected to the gas supply pipeline, a plurality of first gas supply holes are arranged spaced apart on the surface of the hollow cavity facing the substrates, and/or a plurality of second gas supply holes are arranged spaced apart on the outer circumferential surface of the hollow cavity.

12. The wafer boat according to claim 8, wherein a regulating valve is disposed between each layer of the gas supply components and the gas supply pipeline, and the regulating valve is used for adjusting the gas supply flow rate of the corresponding gas supply component.

13. The wafer boat according to claim 8, wherein the wafer boat further comprises a plurality of heaters spaced apart along the vertical direction, and the heaters are configured to heat central regions of the substrates when the wafer boat carries the substrates.

14. The wafer boat according to claim 13, wherein the heaters are disposed opposite the central regions of the substrates, and the heaters are arranged above or below the substrates adjacent thereto in a contact manner or a non-contact manner.

15. A furnace tube apparatus, comprising a process tube and the wafer boat

according to any one of claims 8 to 14, wherein the wafer boat is disposed inside the process tube, multiple layers of exhaust ports are arranged on a side wall of the process tube along a vertical direction of the process tube, and each layer of exhaust ports corresponds to at least one layer of the gas supply components.

16. The furnace tube apparatus according to claim 15, wherein each layer of the exhaust ports includes a plurality of openings spaced circumferentially.

17. The furnace tube apparatus according to claim 16, wherein the multiple layers of gas supply components and the multiple layers of exhaust ports are in a one-to-one correspondence, each layer of the gas supply components is provided with a plurality of second gas supply holes spaced circumferentially, and the plurality of second gas supply holes correspond to the plurality of openings of the corresponding layers.

18. The furnace tube apparatus according to claim 15, further comprising:

a liner tube, sleeved on the outer side of the process tube;

a heating assembly, disposed on the outer side of the liner tube, and configured to heat the liner tube.

19. The furnace tube apparatus according to claim 18, wherein the liner tube is provided with a plurality of extraction ports spaced circumferentially, and a gas pump is disposed at each extraction port.