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A VERTICAL BOAT AND A METHOD FOR MAKING THE SAME

The invention relates to a vertical boat for holding a plurality of semiconductor wafers and a method for making the same, which comprises two end members and a plurality of support members vertically mounted on the end members.

In an oxidation and/or a diffusion process, a wafer boat loaded with a plurality of semiconductor wafers is transferred into a diffusion furnace, and the wafers are subjected to a predetermined heat treatment.

Either a vertical boat or a horizontal boat is selected according to the type of the diffusion furnace.

A conventional vertical boat has two end plates and a plurality of, for example four, vertical support bars mounted on the end plates. A plurality of wafers are held in horizontal or somewhat inclined manner on the vertical boat. A plurality of slits are formed on the support member at a predetermined interval for relieving semiconductor wafers.

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In the conventional vertical boat all support members have, normally, the same configuration in cross section. The support member is, for instance, a triangle bar or a rectangle bar. Each slit formed on such a bar member has an arc-shaped inner bottom corresponding to the periphery of the wafer. Thus, a support surface formed on the slit has only a small extension in the circumferencial direction of the wafer.

On the other hand, Japanese Utility Model laid open No.62-128633 discloses a boat which comprises circular arc plates fixed on support bars, wherein the loading stress of the large wafer can be somewhat relaxed. However this boat is expensive because the circular arc plate must have very accurate surface on which the wafer is to be placed.

During heat treatments not only wafers but the boat, regardless of its shape, is heated upto a high temperature. The larger the wafer is, the more it is apt to be deflected by its own weight when heated upto a high temperature. It is because the wafer is supported only by its peripheral portions in the conventional vertical boat. Thus the wafer is apt to be deformed and slipped, and a crystal dislocation is caused. Consequently the yield will go down. By slip is meant crystal defect or crystal dislocation.

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On the other hand the load of the wafers is not equally distributed among support members. In other words the load is concentrated to a specific support members. As the result, the larger the wafer is, the more frequently slips are caused.

In the conventional boat, two front support members located on the wafer inserting side are spaced somewhat larger than the outer diameter of the wafer for forming a space between the two support members large enough to insert and to take out the wafers. When the wafer is properly loaded on the support members, the angle between a line linking a front edge of the front support member to the gravity center of the wafer and the wafer inserting direction is about 90 degrees. In such a positioning, the gravity center of the wafer is approximately located between the front edges of the two front support members or its neighborhood so that the load of the wafers is biased on the two front support members. As the result the two front support members share, for example, 70-90% of the weight of the wafers.

There is also thermal stress resulted from temperature difference between the wafer and the slit portions of the support member engaging the wafer.

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Therefore the larger the wafers are, the more frequently slip dislocations are caused.

When the wafers are subjected to a heat treatment, heat is transferred to the wafers not only by radiation from the diffusion furnace but by direct heat transfer from the slit portions of the support members engaging with the wafer. The latter, particularly, results in partial temperature difference on each wafer. Stress caused on the wafer not only by its own weight but by the temperature difference leads to slip dislocation of the wafer especially near the two front support members. As a result, during heat treatments, the yield of wafers will go down.

Summary of the Invention

An object of the present invention is to provide a vertical boat wherein no slip dislocation is caused and the deflection of the wafer is considerably decreased even when the large wafers are held thereon.

According to the present invention a vertical boat for holding a plurality of semiconductor wafers is provided, which comprises two end members positioned at the top and the bottom

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of the vertical boat, and a plurality of support members vertically mounted on the end members for supporting the wafers, wherein each support member is formed by a plate-like member having a series of slits formed thereon in such a manner that a plurality of support arms are defined by the slits at a predetermined interval, each support arm having a support projection formed at the end thereof, and wherein the inner portions of the wafer is to be supported by the support projections whereas the periphery of the wafer is non-contact with the arms of the support members.

Each slit extends over preferably $2/3$ of the width of the support member or more, and more preferably it extends over $3/4$ of the width of the support member or more.

The inner portions to be supported by the support projections are preferably concentric about the center of the wafer. And the inner portions are preferably spaced from the center of the wafer by 50-90%, more preferably 65-85%, of the radius of the wafer.

The inner portions are preferably positioned in such a manner that the load of the wafers are almost equally distributed among the support members.

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The section modulus of the support member is preferably 0.3-3.0, more preferably 0.5-2.5, cubic centimeters for realizing sufficient strength as the support member.

According to the inventive vertical boat, deflection and curvature of the wafer is considerably decreased, and slip is effectively inhibited. Therefore when the wafer held on the inventive boat are subjected to a heat treatment, quality of the wafers and the yield can be improved, and the time required for the heat treatment process can be decreased.

According to the prevent invention, the support projections support the wafer not by the periphery portions but by the inner portions so that the periphery portion of the wafer does not engage with the support members. As a result, the loading concentration on a specific support member can be decreased. It is because when the wafer is placed properly on the boat, the gravity center of the wafer can be positioned so as to be substantially equally spaced from all support members. In other words, the load of the wafer can be almost equally distributed among all support members. Therefore slip dislocation of the wafer is effectively inhibited.

According to the invention, deflection of the wafer by its own gravity is decreased, because the support projects support



the wafer not by the peripheral portions but by the inner portions. Consequently crystal dislocation on the wafer can be inhibited even if the wafer is large, which is caused in prior art by deformation or stress of the wafer. As the result the yield is improved.

According to this invention, temperature differences and heat-stress on each wafer can be effectively decreased, which are mainly caused by direct heat transfer from peripheral portion of the wafer engaging with the support member in the prior art. It is because the support members support the wafer by the small inner portions, while the peripheral portions of the wafer do not engage the support members. Therefore crystal dislocation on the wafer can be more effectively inhibited, and the yield is further improved.

According to the present invention, a process for producing a vertical boat is also provided, which comprises steps of forming a series of first slit portions on a plate-like member at a predetermined interval in such a manner that two longitudinal side walls of the plate-like member are remained, and forming a series of second slit portion on one of the longitudinal side walls at the same interval in such a manner that the first and the second slit portions are connected each



other so as to define a series of arms each having a small support projection at the end near the center axis of the vertical boat.

The plate-like member is, for example, a plane plate, a pipe, a pipe-like plate and so on. The plate member can have a J-shaped, a U-shaped, a C-shaped, a L-shaped, or a V-shaped cross section. In case of a L-shaped or a V-shaped cross section, the corner angle is arranged to, for example, 45-150 degrees.

According to the inventive method, a vertical boat having very accurate slits can be mass produced. Especially, the width and the intervals of the slits can be formed with high accuracy.

Embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings of which:

Fig. 1 is a schematic sectional view showing a first embodiment of a vertical boat according to the present invention;

Fig. 2 is a sectional view showing one of the support members of the vertical boat of Fig. 1;

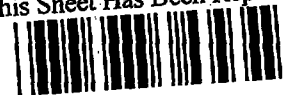


Fig. 3 is a schematic sectional view, taken along lines I-I of Fig.4, showing a second embodiment according to the present invention;

Fig. 4 is a schematic front view showing the vertical boat of Fig. 3, wherein slits on the upper and lower portions are illustrated but slits on the middle portion are omitted;

Fig. 5 is a left side view showing the vertical boat of Fig. 3, wherein slits on the middle portion are omitted;

Figs. 6(A),(B) are views showing processes of producing one of support members of Fig. 3, Fig. 6(A) showing a left side of the support members of Fig. 6(B), Fig. 6(B) showing a section taken along lines IV-IV of Fig. 6(A);

Figs. 7(A),(B) are views showing one of support members of Fig. 3, Fig. 7(A) showing left side of the support members of Fig. 7(B), Fig. 7(B) showing a section taken along lines V-V of Fig. 7(A);

Figs. 8(A),(B) are views showing processes of producing the other support member of Fig. 3, Fig. 8(A) showing a left side of the support members of Fig. 8(B), Fig. 8(B) showing a section taken along lines VI-VI of Fig. 8(A);



Figs. 9(A),(B) are views showing the other support member of Fig. 3, Fig. 9(A) showing left side of the support members of Fig. 9(B), Fig. 9(B) showing a section taken along lines V-V of Fig. 9(A);

Fig. 10 is a schematic sectional view showing partially a third embodiment according to the present invention.

Figs. 1,2 show a first embodiment of a vertical boat according to the present invention. The vertical boat for holding a plurality of wafers 1 comprises two end plates 2 located at the top and the bottom of the boat, and three or more, normally four, support members 5,6 mounted vertically on the end plates 2. Only the bottom end plate 2 is shown in Fig. 1. The support member 5,6 is generally a plate whose cross section is a long rectangle. A series of slits 9,10 for receiving wafers 1 are formed on each support member 5,6.

The slits 9,10 extend over $2/3$ or more, preferably $3/4$ or more, of the width of the support members 5,6. By the slits 9,10 a plurality of arms for supporting wafers 1 are defined as shown in Fig. 2, which extend horizontally and are parallel one another. A small support projection 13,14 is formed at the end



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of each arm in such a manner that the support projections 13,14 support the wafer by the inner portions P, whereas the arms extend over the peripheral portion of the wafer in non-contact manner. The inner portions P of the wafer 1 to be supported by the support projections 13,14 are preferably spaced from the center 1a of the wafer 1 by 50-90% of the radius of the wafer 1. And the inner portions P of the wafer 1 are preferably concentric around the center 1a of the wafer 1.

No peripheral portions of the wafer 1 contacts with the support projections 13,14 of the arms so that the heat does not transfer directly via the peripheral portion from the support members 5,6 to the wafer 1. Also, stress concentration on the peripheral portion of the wafer 1 is decreased.

The height of the support projection 13,14 is preferably 0.3-3mm to ensure sufficient gas circulation. The width of the slit 9,10 is large enough to restrain heat transfer from the boat to the wafer and to prevent a gas from stagnating between the wafer and the arm.

The vertical boat maybe made of silica glass, silicon carbide, carbon, monocrystal silicon, polycrystal silicon, silicon carbide preganated with silicon and so on, which has preferably a

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high purity, a large heat resistance and a large corrosion resistance. In the case of silica glass, welding is convenient for connecting the members, while in the other cases they are assembled in a predetermined manner.

Two types of support members 5,6 are used in this embodiment, and they are vertically mounted on the end members 2 parallel to each other.

The support members 5,6 have different lengths and different widths in cross section. Two front support members 5,5 located on the wafer inserting side are formed by relatively thin plates. The cross section of the plate 5 is generally a wedge-shape. The slits 9 are formed at predetermined intervals on the support member 5 as shown in Fig. 2. The slits 9 are parallel each other and extend over approximately $4/5$ of the width of the support member 5. By the slits 9 a plurality of arms are defined so that the support member 5 looks like a comb. The slit 9 is formed by a first slit portion 9a and a second slit portion 9b as shown in Fig. 2. The first slit portion 9a is longer and wider than the second slit portion 9b. Thereby a small support projection 13 is formed at the end of each arm. The support projection 13 has relatively a small area, for instance, 12 square millimeters. Two support members 5,5 are positioned so as to face one another.



The other two support numbers 6,6 on the rear side are formed by thicker plates than the support member 5. The cross section of the plate 6 is generally a wedge-shape. The slits 10 are formed at predetermined intervals on the support members 6,6 in the similar manner to the support member 5. The slits are parallel each other and extend over approximately $3/4$ of the width of the support member 6. By the slits 10 a plurality of arms are defined so that the support member 6 looks like another comb. The slit 10 is formed in the similar manner to the slit 9. A support projection 14 is also formed at the end of each arm. The support projection 14 has relatively a small area, for instance, 12 square millimeters. The support members 6,6 are positioned so as to face the center 1a of the wafer 1.

The wafer 1 is supported by the support members 5,6 in such a manner that the inner portion P of the wafer 1 is supported by the support projections 13,14, whereas no periphery portion of the wafer contacts to the arms of the support member 5,6.

The slit 9 of the front support member 5 is so formed that the slit bottom 9c is parallel to the wafer inserting direction X. While the slit 10 of the rear support member 6 is so formed that the slit bottom 10a thereof is parallel to the tangent line of the circumscribing circle of the wafer 1.



When the wafer 1 is placed properly on the boat, the support projections 9,10 support the wafer not by the peripheral portions but by the inner portions P. The inner portions P are preferably concentric around the center 1a of the wafer 1, and preferably spaced from the center 1a of the wafer 1 by 50%-90%, preferably 65%-85%, of the radius of the wafer 1.

The support portions P of the wafer 1 to be supported by the support projections 13,14 are distributed in circumferential direction in such a manner that the angle between a line linking the support projection 14 of the rear support member 6 to the center 1a of the wafer 1 and the wafer inserting direction X is 75-180 degrees, preferably 95-140 degrees. Whereas the angle defined by a line linking the support projection 13 of the front support member 5 to the center 1a of the wafer 1 and the inserting direction X is 30-120 degrees, preferably 30-80 degrees.

The support projections 13,14 can be distributed in the other manner. For example, the two projections 13,13 of the front support members 9,9 and the two projections 14,14 of the rear support members 10,10 are positioned so as to be symmetric relative to lines M and N shown in Fig. 1. The line M passes through the center 1a of the wafer 1 and is parallel to the



wafer inserting direction X, while the line N passes through the center 1a of the wafer 1 and is perpendicular to the wafer inserting direction X. In this manner the load of the wafer 1 is distributed equally among four support projections 13,14 thereby the wafer 1 can be supported in good balanced manner. The wafer 1 is placed on the boat in such a manner that the center 1a of the wafer approximately coincides with the center line of the vertical boat.

The support members 5,6 can be produced in the following manner. First, a plate member 5 (6) is provided, whose cross section is generally wedge-shape as shown in Fig. 1. Then a series of first slit portions 9a, of which size is for example 29 x 5.35 mm, are formed on the plate member 9 (10) between two sides thereof at a predetermined interval, for example 3 mm, by water jet, for example. Thereby a plurality of windows are formed in series along longitudinal direction of the plate member 5 (6) and side walls 5a,5b are remained. One side wall 5b is, for example, two or three times thicker than the other side wall 5a.

Next, second slit portions 9b are formed on the thin side wall 5a at predetermined intervals, for example 3 mm, by a diamond cutter. The second slit portion 9b has a small width and connects to the corresponding first slit portion 9a.



Thereby a series of arms each having a support projection 13 (14) at the end thereof are defined by the first and the second slit portions 9a, 9b. The arms horizontally protrude from the thick side wall 5b so that the thick side wall 5b acts as a support column. The support projection 13 (14) is, for example, 1 mm in height and has a small top surface for supporting the inner portions P of the wafer 1. Thus comb-shaped support members 9 (10) as shown in Fig. 2 are formed.

After forming the first slit portions on the plate members, the plate members can be fixed on one or two end members after that the second slit portions can be formed on the plate members. By this method, the slits can be formed with good accuracy.

After forming the first slit portions on the plate members, the plates can be impregnated with Si and then the second slits can be formed. In this manner, the second slit portions can be easily machined.

When the slits is formed on the support members in said manner, high accuracy slits can be formed because the cutting volume is very small in the second step.

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Figs. 3-9, and Fig. 10 show a second and a third embodiments of the vertical boat according to the present invention, respectively. The vertical boat, in each case, comprises two end plates located on the top and the bottom of the boat, and three or more, normally four, support members 3,4,104 vertically mounted on the end plates. Each support member 3,4,104 has a series of slits 7,8,108 at predetermined intervals along longitudinal direction thereof. Each support member 3,4,104 is generally a long plate or a long plate-like member.

The slits 7,8,108 extend over $2/3$ or more, preferably $3/4$ or more, of the width of the support members 3,4,104. By the slits 7,8,108 a series of arms are defined on the support members 3,4,104. Each arm has support projections 11,12,112 at the end thereof in such a manner that the support projections 11,12,112 support the inner portion P of the wafer 1, while the arms extend over the periphery of the wafer in non-contact manner. Said inner portions P of the wafer 1 to be supported by the support projections 11,12,112 are preferably concentric about the center 1a of the wafer 1, and are preferably spaced from the center 1a of the wafer 1 by 50%-90% of the radius of the wafer 1.

In the second embodiment each support member 3,4 is arc or



circular arc in cross section. The cross section of the support member can be a L-shape, a J-shape, a boomerang-shape or other curved-shape. The support members 3,4 can be formed by longitudinally cut pipe. While the support member 104 is generally a pipe in the third embodiment. The thickness of each support member 3,4 104 is constant, but it can be decreased gradually toward their ends. Thus the support members can be modified in various forms, and the combination of the support members is not restricted to the illustrated embodiments.

No peripheral portions of the wafer contacts to the support projections 11,12,112 of the support members 3,4,104 so that heat does not transfer via the peripheral portions from support members to the wafer and weight concentration on the peripheral portion is decreased.

The height of each support projection 11,12,112 is enough that the periphery of the wafer does not contact to the arms of the support members 3,4,104. However it is preferably 0.3-3mm for ensuring sufficient gas circulation. Thus the slits are relatively large so that heat transfer from the boat to the wafer is restrained and the gas is prevented from stagnating between the wafer and the arms.

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The support projections 11,12,112 are preferably positioned in such a manner that the loads of the wafers 1 are equally distributed among all the support members 3,4 104 and the deflection of each wafer 1 is considerably decreased.

Further details of the second and third embodiments are explained hereinafter.

In second embodiment shown in figs. 3-9 the vertical boat has two kinds of support members 3,4. The support members 3,4 are generally semi-circular arc plates having different radii of curvature. Two front support members 3,3 are located near the wafer inserting side and faces one another. The radius of curvature of the support member 3 is larger than that of the support member 4. The support member 3 has a plurality of slits 7 at a interval D1 as shown in Figs. 4,5. The slits 7 extend over about 5/6 of the width of the support member 3. A plurality of arms are defined by the slits 7. Each arms has at its end a small support projection 11. The support projection 11 has at its top a small support surface, the area of which is for example 10-150 square millimeters. The support projection 11 is formed so as to support the inner portion P of the wafer 1, whereas the other portions of the arm do not contact with the periphery of the wafer 1.



Other support members 4,4 are located on the rear side and have relatively small radii of curvature. The support member 4 has a plurality of slits 8 at a interval D_2 as shown in Figs. 6,7. The slits 8 extend over about $4/5$ of the width of the support member 4. A plurality of arms are defined by the slits 8. Each arm has at its end a small support projection 12. The support projection 12 has at its top a small support surface, the area of which is for example 10-50 square millimeters. The support projection 12 is formed so as to support the inner portion P of the wafer 1, whereas the other portions of the arms do not contact with the periphery of the wafer 1.

The slit 7 is formed by a first long slit portion 7a with relatively a large width and a second short slit portion 7b with relatively a small width. The slit 8 is also formed by a first long slit portion 8a with relatively a large width and a second short slit portion 8b with relatively a small width.

The inner portions P of the wafer 1 to be supported by the support projections 11,12 are preferably located concentric about the center 1a of the wafer 1, and are preferably spaced from the center 1a of the wafer 1 by 50-90%, more preferably 65-85%, of the radius of the wafer 1. Therefore the periphery



portion of the wafer 1 is not supported by the support projections 11,12.

The support projections 11,12 are preferably distributed in circumferential direction in such a manner that the angle A formed between the wafer inserting direction X and a line linking the support projection 12 of the rear support member 4 to the center 1a of the wafer 1 is 75-180 degrees, more preferably 95-140 degrees. On the other hand the angle B formed between the wafer inserting direction X and a line linking the support projection 11 of the front support member 3 to the center 1a of the wafer 1 is preferably 30-120 degrees, more preferably 30-80 degrees.

The support projections 11,12 can be distributed in the other manner that the two projections 11,11 of the front support members 3,3 and the two projections 12,12 of the rear support members 4,4 are symmetrical with respect to a line M and a line N shown in Fig. 3. The line M passes through the center 1a of the wafer 1 and is parallel to the wafer inserting direction X, while the line N passes through the center 1a of the wafer 1 and is perpendicular to the wafer inserting direction X. In this manner the load of the wafer 1 is distributed equally among four support projections 11,12 thereby the wafer 1 can be supported in a good balanced manner.



The support member 3 of the second embodiment shown in Figs. 3-9 can be produced in following manner. First a pipe member having a relatively large diameter is vertically cut so as to provide a long plate member of which cross section is approximately quarter-circular arc. The pipe member has, for example, an outer radius R_1 of 40mm and an inner radius R_2 of 34mm. The long plate member extends circumferentially over, for example, 100 degrees around the center O_1 in cross section.

Next a series of first slit portions 7a are formed at the interval D_1 , for example 12.7mm, on the plate member. The first slit portions 7a has a width of W_1 , for example 7mm, and extends circumferentially over 60-80 degrees around the center O_1 , which is corresponding to a length L_1 in Fig. 4. The length L_1 is for example 30mm. The first slit portion can formed by a laser (beam) machine, a high pressure jet, a milling cutter, a lathe, a diamond cutter and so on. Both longitudinal side walls 3b, 3c are remained as shown in Figs. 6(A), 6(B). The side wall 3c is thicker than the other side wall 3b so as to acts as a column. The thinner wall 3b extends circumferentially over several degrees around the center O_1 .

Then a series of second slit portions 7b are formed on the side-wall 3b by a diamond cutter. The second slit 7b has a



width W_2 of 3.2mm, for example. The second slit portion 7b is cut from the outer surface 3b so as to be connected to the corresponding first slit portion 7a. Thereby a series of arms each having a support projection 11 at the end thereof are defined by the first slit portions 7a and the second slit portions 7b as shown in Figs. 7(A), 7(B). The support projection 11 has a height of H , for example 1.9mm, and has a small support surface.

The other support member 4 in Figs. 3-9 can be produced in a following manner. First a pipe member having a relatively small diameter is vertically cut so as to provide a long plate member of which cross section is approximately semi-circular arc. For example, the pipe member has an outer radius R_3 of 17.5mm and an inner radius R_4 of 10mm. And the long plate member extends circumferentially over, for example, 225 degrees around the center O_2 in cross section.

Next a series of first slit portions 8a are formed at the interval D_2 , for example 12.7mm, corresponding to the interval D_1 of slit 7 on the plate member 3. The first slit portions 8a has a width of W_3 , for example 7mm, and extends circumferentially over 180 degrees around the center O_1 . The first slit portion can be formed by a laser (beam) machine, a high



pressure jet, a milling cutter, a lather, a diamond cutter and so on. Both vertical side walls 4b,4c are remained as shown in Figs. 8(A),8(B). The side wall 4c is thicker than the other side wall 4b so as to act as a column. The thin wall 4b extends circumferentially over 20 degrees around the center O2, while the thick wall 4c extends over 40 degrees.

Then a series of second slit portions 8b are formed at intervals D2, for example 12.7mm, on the side wall 4b by a diamond cutter. The second slit portion 8b has for instance a width W4 of 3.2mm. The second slit portion 8b is cut from the outer surface 4a so as to be connected to the corresponding first slit portion 8a. Thereby a series of arms each having a support projection 12 at the end thereof are defined by the first slit portions 8a and the second slit portions 8b as shown in Figs. 9(A),9(B). The support projection 12 has, for example a height of 1.9mm, and a width W5 of 3mm.

Four support members 3,4 and the slits 7,8 are symmetrical with respect to the plane including the central axis of the boat and parallel to the wafer inserting direction X. However they can be positioned in other manners.

Fig. 10 shows the third embodiment according to the present

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invention. Four pipe-shaped support members 104 are vertically mounted on two end members 2 located at the top and the bottom of the vertical boat. Two front support members 104 located on the wafer inserting side have relatively large diameters for forming a space large enough to insert and to take out the wafers, whereas two rear support members 104 located on the rear side have relatively small diameters for realizing a light-weight construction. However all support members 104 can have the same diameter. On the other hand, the thicknesss of the support members can be varied taking into account mechanical strength. In any case section modulus of the support member 104 is preferably 0.3-3.0 cubic centimeter, more preferably 0.5-2.5 cubic centimeter.

The support members 104 have a series of slits 108 formed at the same interval. The slits 108 can be formed in a following manner. First two series of first slit portions are formed at the same interval from both sides on the pipe member 5. The first slit portion extends over $2/3$, $3/4$ of the diameter of the pipe member 5 in case the front and the rear support members, respectively. Thereby two side walls are remained in each case.

Next a series of second slit poritons are formed on one of

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the walls at the same interval as the first slit portions by a diamond cutter. Each second slit portion is connected to the corresponding first slit portion. The second slit portion has a smaller width than the first slit portion. The second slit portion has a width of 3.2mm, for example. Thereby a series of arms each having a support projection 112 formed at the end portion near the central axis of the vertical boat are defined by the first and second slit portions. In this case the end portion is not a free end but a middle end portion.

The support projection 112 has a small support surface formed at the top thereof. It has the area of for example 5-50 square millimeters. The wafer is supported in such a manner that the inner portions of the wafer are supported by the support projections 112 whereas the periphery of the wafer is not contact with the arms defined by the slits 108. The inner portions are preferably concentric about the center 1a of the wafer 1 and spaced from the center 1a by 50-90% of the radius of the wafer so that the periphery of the wafer does not supported by the support projections 112 of the arms.

The circumferential positioning of the support projections 112 is the same as the support projections 11,12 of the second embodiment.



In producing the support members 3,4,104, after forming the first slit portions on the plate-like members, all plate member can be fixed on one of or both the end members and then the second slit portions can be formed on the plate-like members. In this method, the slits can be formed with good accuracy.

On the other hand after forming the first slit portions on the plate-like members, the plate-like members can be impregnated with Si and then the second slits can be formed. In this manner, the second slit portions can be easily machined.

Example

A vertical boat for 8 inches wafers was formed from monocrystal silicon. The boat had the same construction as the boat shown in Figs. 3-9. Also, a conventional vertical boat having four support members was prepared for comparative tests.

A value of deflection of the wafer was calculated by a computer-assisted simulation and actual values were detected by a laser micrometer in cases of the inventive boat and the conventional boat, respectively. The results are shown in following table 1. As shown in Table 1, the wafer held on the conventional boat was deflected by 30 microns or more,

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whereas the wafer held on the inventive boat 5 microns or less. Thus in the inventive boat deflection of the wafer was much smaller than in the prior art.

Next values of curvature during a heat treatment were detected. The results are shown in Tables 2. The heat treatment was an oxidation process at the temperature of 1000 degrees celsius for 100 hours. Values of curvature were detected by a laser micrometer.

Also, the number of the slips and the length thereof caused during heat treatments 1)-3) were detected. The results are shown in Table 3. The heat treatments 1)-3) were operated according to Table 4.

As shown in tables 2,3, in case of the inventive boat the curvature was smaller than in the prior art and slips rarely occurred.

Thus, by using a vertical boat according to the present invention, deflection and curvature of the wafer was decreased, and slip was effectively inhibited during heat treatments. It is mainly because the inner portions of the wafer were supported by the support projections of the arms whereas periphery portion of the wafer did not contact to the arms of the support members.



[Table 1]

	the prior art	the present invention
computer -assisted simulation	30-180 microns	5 microns
laser micrometer	150 microns	less than 5 microns

[Table 2]

	the prior art	the present invention
	500 microns	less than 5 microns

[Table 3]

	number of wafers	number of wafers having slips	length of the slip
heat treatment(1)	70 (70)	0 (70)	- (10)
heat treatment(2)	70 (70)	0 (20)	- (5)
heat treatment(3)	70 (70)	0 (6)	- (1)

() designates the prior art

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[TABLE 4]

heat treatment(1) (rate degree/min)	insert	→800degrees	→1000degrees	→1100degrees
		celsius	celsius	celsius
		10	6	3
		→1250degrees	→1100degrees	→800degrees
		celsius	celsius	celsius
		3	5	
				→discharge
heat treatment(1) (rate degree/min)	insert	→800degrees	→1000degrees	→1100degrees
		celsius	celsius	celsius
		10	3	2
		→1250degrees	→1100degrees	→800degrees
		celsius	celsius	celsius
		2	3	
				→discharge
heat treatment(1) (rate degree/min)	insert	→800degrees	→1000degrees	→1100degrees
		celsius	celsius	celsius
		5	2	1
		→1250degrees	→1100degrees	→800degrees
		celsius	celsius	celsius
		1	3	
				→discharge

* the heat treatment was performed with
an atmosphere of N2 + 02

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CLAIMS:

1. A vertical boat for holding a plurality of semiconductor wafers comprising:

two end members (2) positioned at the top and the bottom of the vertical boat; and

a plurality of support members (3,4,5,6,104) vertically mounted on the end members (2) for supporting the wafers,

wherein each support member (3,4,5,6,104) is formed by a plate-like member having a series of slits (9,10,7,8,108) formed thereon in such a manner that a plurality of support arms are defined by the slits (9,10,7,8,108) at a predetermined interval, each support arm having a support projection (11,12,13,14,112) formed at the end thereof,

and wherein the inner portions (P) of the wafer (1) is to be supported by the support projections (11,12,13,14,112) whereas the periphery of the wafer (1) is non-contact with the arms of the support members (3,4,5,6,104).

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2. A vertical boat according to claim 1, wherein the inner portions (P) of the wafer (1) to be supported by the support projections (11,12,13,14,112) are spaced from the center (1a) of the wafer (1) by 50%-90% of the radius of the wafer (1).

3. A vertical boat according to claim 2, wherein the inner portions (P) of the wafer (1) to be supported by the support projections (11,12,13,14,112) are spaced from the center (1a) of the wafer (1) by 65%-85% of the radius of the wafer (1).

4. A vertical boat according to any preceding claim, wherein the inner portions (P) of the wafer (1) to be supported by the support projections (11,12,13,14,112) are concentric about the center (1a) of the wafer (1).

5. A vertical boat according to any preceding claim, wherein the slits extend over $2/3$ or more of the width of the plate-like member.

6. A vertical boat according to claim 5, wherein the slits extend over $3/4$ or more of the width of the plate-like member.

7. A vertical boat according to claim 6, wherein the slits extend over $4/5$ or more of the width of the plate-like member.





8. A vertical boat according to any preceding claim, wherein the plate-like member has a cross section selected from the group consisting of a long rectangle, a wedge, a pipe, a circular arc, a L-shape, a J-shape, a C-shape and a V-shape.

9. A vertical boat according to any preceding claim, wherein the support members (3,4,5,6) consist of two front support members (3,5) and two rear support members (4,6), the four support members (3,4,5,6) being symmetrical with respect to a plane including the central axis of the vertical boat and parallel to the wafer inserting direction (X).

10. A vertical boat according to claim 9, wherein the support portions (P) of the wafer (1) to be supported by the projections (11,12,13,14,112) are distributed in circumferential direction in such a manner that the angle (A) formed by the wafer inserting direction (X) and a line linking the support projection (12,14) of the rear support member (4,6) to the center (1a) of wafer (1) is 75-180 degrees, and that the angle (B) formed by the wafer inserting direction (X) and a line linking the support projection (11,13) of the front support member (3,5) to the center (1a) of the wafer (1) is 30-120 degrees.

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11. A vertical boat according to claim 9, wherein the support portions (P) of the wafer (1) to be supported by the projections (11,12,13,14,112) are distributed in circumferential direction in such a manner that the angle (A) formed between the wafer inserting direction (X) and a line linking the support projection (12,14) of the rear support member (4,6) to the center (1a) of wafer (1) is 95-140 degrees, and that the angle (B) formed between the wafer inserting direction (X) and a line linking the support projection (11,13) of the front support member (3,5) to the center (1a) of the wafer (1) is 30-80 degrees.

12. A vertical boat according to either one of claims 9 to 11, wherein the inner portions (P) of the wafer (1) to be supported by the support projections are symmetrical with respect to a plane including the central axis of the vertical boat and perpendicular to the wafer inserting direction (X).

13. A vertical boat according to any preceding claim, wherein the section modulus of the support member (3,4,5,6,104) is 0.3-3.0 cubic centimeters.

14. A vertical boat according to claim 13, wherein the section modulus of the support member (3,4,5,6,104) is 0.5-2.5 cubic centimeters.

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15. A method for producing a vertical boat according to any one of the preceeding claims comprising the steps of:

forming a series of first slit poritons on the plate-like member at a predetermined interval along the longitudinal direction thereof so as to remain two side walls of the plate-like member; and

forming a series of second small slit portions on one of the side walls at the same interval so as to connect each second slit portion to the corresponding first slit portion.

16. A method according to claim 15, wherein the first slit portions are formed by a cutting devices selected from the group consisting of a water jet machine, a laser machine, a high pressure jet machine, a milling cutter, a lathe, and a diamond cutter.

17. A method according to claim 15 or 16, wherein the second slit portions are formed by a diamond cutter.

18. A method according to any one of claims 15 to 17, wherein after forming the first slit portions the plate-like members are mounted one or two end members (2), after that the second slit portions are formed.



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19. A method according to any one of claims 15 to 18, wherein after forming the first slit portions the plate-like members are impregnated with Si, after that the second slit portions are formed.

20. A vertical boat substantially as hereinbefore described with reference to Figures 1 and 7, or to Figures 3 to 9, or to Figure 10 of the accompanying drawings.

21. A method of forming a vertical boat substantially as hereinbefore described with reference to Figures 1 and 2, or to Figures 3 to 9, or to Figure 10 of the accompanying drawings.

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