Title: SUSCEPTORLESS SEMICONDUCTOR WAFER SUPPORT AND REACTOR SYSTEM FOR EPITAXIAL LAYER GROWTH

Abstract: A reactor system for use in growth of an epitaxial layer of semiconductor material on a semiconductor wafer. The reactor system includes a reaction chamber including an inlet and an outlet, each of the inlet and outlet being configured to flow a source gas across the reaction chamber. The reactor system also includes a wafer support positioned at least partially within the reaction chamber, the wafer support including a contact member coupled to a hub by an arm, and a void adjacent the arm. The reactor system additionally includes a semiconductor wafer including a front side and a back side, the wafer being positioned substantially horizontally within the reaction chamber intermediate the inlet and the outlet such that the back side rests directly upon the contact member of the wafer support. Typically, the reaction chamber is configured to direct flow of a source gas horizontally from the inlet to the outlet across the wafer such that the gas flows directly over the front side of the wafer, and flows through the void to contact the back side of the wafer. The reactor system may include a heat energy source positioned below the wafer and configured to radiate heat energy to the wafer through the void in the wafer support. Typically, the void extends from the back side of the wafer to the bottom of the reaction chamber. The wafer support does not include a susceptor.
SUSCEPTORLESS SEMICONDUCTOR WAFER SUPPORT AND REACTOR SYSTEM FOR EPITAXIAL LAYER GROWTH

Technical Field

The present invention relates generally to semiconductor wafer fabrication, and more specifically to a reactor system and wafer support for use during epitaxial growth of a semiconductor material on a semiconductor wafer.

Background of the Invention

In the semiconductor wafer manufacturing industry, thin epitaxial layers of semiconductor material, such as silicon or gallium arsenide, are grown on a surface of a semiconductor wafer. These epitaxial layers, commonly referred to as epilayers, form the material within which many modern integrated circuits are fabricated. In addition, many other devices, including optoelectric sensors, light emitting diodes, and micromachined mechanical devices, may be fabricated from epilayer material. As epilayers are a fundamental building block for many technologies, is critical that they be manufactured as efficiently and defect-free as possible, to reduce the cost and increase the quality of the epilayer.

Epilayers may be grown according to a variety of methods, including molecular beam epitaxy (MBE), vapor phase epitaxy (VPE), and liquid phase epitaxy (LPE). In a vapor phase epitaxial reactor, epilayer semiconductor constituents, such as silicon, gallium, arsenic, and germanium, and various dopants such as boron, phosphorous, arsenic, and antimony, are transported to the substrate surface as volatile species suspended in a vapor. Typically, the species are adsorbed onto the substrate at high temperature and diffuse across the surface to form the epilayer.

The VPE process takes place in a reactor including a heat energy source, such as radio frequency (RF) coils or heat lamps, and a susceptor. The susceptor typically is a solid graphite disk underlying and extending to the edge of the wafer and is substantially thicker than the wafer. One or more wafers are placed into the reactor directly on the susceptor, and the heat energy source is activated to heat the susceptor and the wafer. Where a RF heat energy source is used, the susceptor absorbs RF heat energy and conducts heat energy to the wafer. Where heat lamps are used, the
susceptor absorbs heat energy and evenly distributes heat within the wafer, making the wafer less susceptible to temperature gradients within the reaction chamber.

After the wafer has been heated, gas containing the semiconductor constituents for epitaxial growth is introduced to the reactor through an inlet and flowed toward the wafer. Constituents are deposited on the front side of the wafer to form the epilayer. However, contact between the susceptor and the wafer inhibits gas flow to the back side of the wafer, such that constituents do not reach the back side and epilayer growth does not occur on the back side.

Several problems exist with reactors having susceptors. First, the thermal mass of the susceptor must be heated within the reactor along with the wafer before the epitaxial growth process may begin. For each wafer, it is common for the reaction chamber to be heated and cooled several times during the epitaxial growth cycle. For example, after a silicon wafer is inserted into the reaction chamber, the temperature is typically raised for a hydrogen bake of the wafer, which removes silicon dioxide contaminants from the wafer. The chamber is then cooled for epilayer deposition, and is again cooled before unloading of the wafer. After deposition, the chamber typically is heated again, and etch gases, such as hydrogen chloride, are flowed through the chamber to remove semiconductor material from the chamber and susceptor.

When producing epitaxial wafers on a mass scale, heating up and cooling down the susceptor consumes significant amounts of time and energy. In addition, the susceptors require frequent cleaning as semiconductor materials build up on the surface of the susceptors during the epitaxial growth process. Without cleaning, deposits may flake off and contaminate the epilayer growth process. In addition, susceptors must be replaced as their surfaces degrade from repeated epilayer deposition and cleaning, further increasing the materials costs associated with wafer manufacture.

Use of a susceptor for epilayer growth also may induce thermal stresses within the wafer. For example, where RF coils are used to heat the susceptor, the back side of the wafer adjacent the susceptor typically will be hotter than the front side of the wafer during epilayer growth, causing the wafer to bow. Thermally induced strain will develop in the lattice of the bowed wafer as the wafer cools.
Compared to other fabrication procedures, epilayer growth takes place under closely controlled conditions. A prior step in the wafer manufacture process may leave contaminants or imperfections on the surface of the wafer. One effect of the epilayer growth process is to remove these contaminants and correct these imperfections. However, reactors that grow an epilayer on only one side of a wafer, such as reactors that use susceptors, do not remove contaminants or perfect the imperfections on the back side of the wafer. These imperfections and contaminants on the back side may adversely affect a downstream circuit fabrication, test, or measurement procedure.

Where only the front side of a wafer is being coated with an epilayer, there is a risk that dopants within the substrate of the wafer will escape from the back side of the substrate at high temperatures during the epitaxial growth process, enter the gas flow, and contaminate the epilayer growth process on the front side of the wafer. This contamination process is referred to as autodoping, and is highly undesirable.

In addition, use of a susceptor in a reactor requires that the wafer be loaded onto the susceptor by a paddle that picks the wafer up by its top side. Some current reactors commonly utilize paddles that lift the wafer by creating a vacuum through direct suction or according to the Bernoulli effect. Loading and unloading through such vacuum operative paddles is slow, and consumes valuable cycle time per wafer.

**Summary of the Invention**

According to the present invention, a reactor system is provided for use in the growth of an epitaxial layer of semiconductor material on a semiconductor wafer. The reactor system includes a reaction chamber including an inlet and an outlet, each of the inlet and outlet being configured to flow a source gas across the reaction chamber. The reactor system also includes a wafer support positioned at least partially within the reaction chamber, the wafer support including a contact member coupled to a hub by an arm, and a void adjacent the arm. The wafer support may include at least three arms extending radially outward from the hub, and at least three tips, each tip being associated with a respective arm and terminating in a point. The reactor system additionally includes a semiconductor wafer including a front side and a back side, the wafer being positioned substantially horizontally within the reaction chamber.
intermediate the inlet and the outlet such that the back side rests directly upon the contact member of the wafer support. Typically, the reaction chamber is configured to direct flow of a source gas horizontally from the inlet to the outlet across the wafer such that the gas flows directly over the front side of the wafer, and flows through the void adjacent the back side of the wafer. The reactor system may include a heat energy source positioned below the wafer and configured to radiate heat energy to the wafer through the void in the wafer support. Typically, the void extends from the back side of the wafer to the bottom of the reaction chamber. The wafer support does not include a susceptor.

Brief Description of the Drawings

Fig. 1 is a cross-sectional view of a prior art epitaxial reactor including a susceptor.

Fig. 2 is a partial cutaway exploded perspective view of a susceptor assembly of the prior art epitaxial reactor of Fig. 1.

Fig. 3 is a cross-sectional view of a reactor system according to the present invention.

Fig. 4 is a cross-sectional view of another embodiment of a reactor system according to the present invention.

Fig. 5 is a front view of a wafer support according to the present invention.

Fig. 6 is a top view of the wafer support of Fig. 5.

Fig. 7 is a partial view of another embodiment of a contact member according to the present invention.

Fig. 8 is a partial view of yet another embodiment of a contact member of according to the present invention.

Fig. 9 is a partial of view of yet another embodiment of a contact member according to the present invention.

Detailed Description and Best Mode for Carrying Out the Invention

Referring initially to Fig. 1, a prior art epitaxial reactor is shown generally at 10, including a susceptor assembly shown at 12. Prior art reactor 10 includes a reaction chamber 14 flanked on an upper side by an upper heat lamp array 16 and on
a lower side by a lower heat lamp array 18. Susceptor assembly 12 is positioned within reaction chamber 14, and is configured to support semiconductor wafer 20 within reaction chamber 14.

As shown in Figs. 1 and 2, susceptor assembly 12 includes several components, each of which must be heated by the upper and lower heat lamp arrays as the reaction chamber is heated to a process temperature. Susceptor assembly 12 includes a susceptor 22, typically of graphite construction, which acts to absorb heat energy from lamps 16, 18 and to evenly distribute the heat energy to wafer 20 during epitaxial deposition. Susceptor 22 typically includes a depression 36 on its top surface. During epilayer growth, wafer 20 rests upon the susceptor, contacting the susceptor only at an outer edge 38 of the susceptor. As shown in Fig. 1, susceptor 22 rests directly upon posts 32 of tripod 30. Tripod 30 rests upon shaft 34, which is configured to rotate under the influence of a prime mover (not shown).

In operation, the reaction chamber is heated to a process temperature and a source gas containing semiconductor constituents is flowed from inlet 40 to outlet 42, across a front side 46 of wafer 20 on its way through the reaction chamber. Typically, the semiconductor constituents are adsorbed onto the wafer surface at high temperature and diffuse across the surface to form the epilayer.

In prior art reactors such as 10, a susceptor is used to distribute heat to the wafer evenly. Epilayer growth is most uniform when an even temperature is maintained across the entire wafer. In addition, susceptor 22 inhibits epilayer growth on the backside of the wafer by mechanically inhibiting gas flow to the back side of the wafer.

Susceptor assembly 12 also includes a structure called a Saturn ring 23, including mating L-shaped rings 24 and 26, each typically of graphite. Saturn ring 23 is supported on posts 27 of Saturn ring support 28, and is positioned around susceptor 22 such that the susceptor is free to rotate within the Saturn ring.

Saturn ring 23 is used to insulate and control heat transfer at an outer edge of the wafer. Reactors with susceptors typically experience cooling along the perimeter of the wafer due to heat loss to the gas flow. The Saturn ring absorbs heat energy from the heat sources and helps prevent heat loss at the perimeter of the wafer,
thereby keeping the temperature more uniform across the wafer and facilitating uniform epilayer growth.

However, susceptor 22, Saturn ring 23, and Saturn ring support 28 add thermal mass to the reaction chamber. For each wafer, these components must be heated and cooled multiple times during the epilayer growth process. In addition, these components periodically must be cleaned and/or replaced when deposits accumulate on the components from the epitaxial growth process. Therefore, use of these susceptor assembly components consumes great amounts of energy, time, and replacement materials.

Turning now to Fig. 3, an epitaxial reactor system according to the present invention is shown generally at 50. Reactor system 50 includes an upper heat energy source 52 and a lower heat energy source 54 positioned on opposing sides of a reaction chamber 56. Typically, upper heat energy source 52 includes a plurality of heat lamps 62 positioned in an array extending across the top of reaction chamber 56, and lower heat energy source 54 includes a plurality of heat lamps 64 positioned in an array rotated 90 degrees from heat lamps 62 and extending across the bottom of reaction chamber 56. Alternatively, the upper and lower heat energy sources may be RF coils, or another type of heat source. Wafer 58 is heated by heat energy radiating from the upper heat source directly to a front side 66 of the wafer, and from the lower heat energy source directly to a back side 68 of the wafer.

A wafer 58 is positioned directly on a wafer support 60 within reaction chamber 56 during epilayer growth. Wafer support 60 includes a hub 76, which in turn includes a flared portion 78 configured to receive a tapered portion 80 of a shaft 82. Alternatively, hub 76 may incorporate another fastening mechanism to connect to shaft 82, or may be formed integral with shaft 82. Typically, shaft 82 is connected at a lower end to a rotation and translation mechanism (not shown) that is configured to rotate, raise, and lower the shaft and wafer support within the reaction chamber. Rotation of the wafer ensures that radiant heat energy and source gases containing reactants are evenly distributed to all regions of the wafer. Alternatively, the shaft and wafer support may be configured only to rotate, or move up or down, or the shaft and wafer support may not move at all.
Wafer support 60 also includes arms 84 mounted at an inward end to hub 76 and extending radially outward from the hub, as shown in Figs. 5 and 6. Typically arms 84 extend linearly outward at right angles from the hub. Alternatively, arms 84 may extend outward in a curved, spiraling, angled, or other fashion. Typically wafer support 60 includes three arms. Alternatively, a different number of arms may be employed, such as one arm, or five arms. If one arm is used, that arm may support, for example, a curved member that extends sufficiently around a perimeter of the wafer to support the wafer.

Arms 84 usually are connected at a distal end to contact members 86. Alternatively, contact members 86 may be connected to arms 84 at some other location, such as intermediate the inward end and distal end of arms 84. Typically, one contact member 86 is positioned on each arm 84. Alternatively, a plurality of contact members may be positioned on a single arm.

As shown in Fig. 6, wafer support 60 includes voids 70 disposed adjacent arms 84. Where wafer 58 is positioned for epilayer growth on wafer support 60 within reaction chamber 56, voids 70 typically extend from back side 68 of wafer 58 to a bottom 71 of the reaction chamber. Voids 70 are configured to facilitate gas flow to back side 68 of wafer 58. In addition, voids 70 are configured to allow heat energy to radiate from lower heat energy source 54, through the bottom 71 of the reaction chamber, through the voids 70, directly to the back side 68 of wafer 58, without being absorbed by an interfering susceptor or wafer support structure. Typically, reaction chamber 56, including bottom 71, and wafer support 60 are made of quartz, and are substantially thermally transparent, allowing radiant heat energy to pass directly through their structures.

Contact members 86 each typically include a shaft 88 and a tip 90 adjacent an upper end of the shaft. Each tip 90 typically includes a taper terminating in a point 92. The taper of contact members 86 is usually linear, extending inward towards a central longitudinal axis of the shaft at a 30 degree angle from the vertical axis. Alternatively, the taper may be of another angle, such as 45 degrees, or may be curved or some other irregular shape. For example, the tip may be hemispherical or
elliptical. Point 92 is typically fire polished and formed with a radius of 0.5 millimeters or less.

Tip 90 and shaft 88 may be formed as an integral structure, as shown in Fig. 5. Alternatively, the contact member and arm may be separable. As shown in Fig. 7, contact member 86 may include a recess or hole 94 configured to mount upon a projection or post 96 of arm 84. In addition, as shown in Fig. 8, contact member 86 may include a projection or post 98 configured to mount in a recess or hole 100 of arm 84. As shown in Fig. 9, contact member 86 may include a shaft 102 that is taller than hole 100, and which terminates in a tip 104.

In the embodiments shown in Figs. 7-9, the contact member is removable from the arm and replaceable, such as may be required when deposits from the epi process build up on the surface of the contact member. The contact member is often made of quartz, such that deposits do not easily build up on the contact member and radiant heat energy may easily pass through the contact member. Alternatively a portion or the entirety of the contact member may be formed of some other material, such as carbide.

Contact members 86 typically are configured with each tip 90 terminating in a point 92 such that minimum contact with wafer 58 is made during epilayer growth. Because the epilayer growth process is extremely sensitive to changes in wafer temperature, it is desirable to minimize contact with the wafer. Contact with the wafer will result in conductive heat transfer between the wafer and contact member. Conduction will result in a temperature gradient in the wafer that produces imperfect or uneven epilayer growth. In addition, the contact member may interfere in radiation of heat energy from the lower heat energy source to the wafer, thereby causing a region of the wafer to receive less heat energy, and be cooler, than surrounding regions. This interference will result in changes in epilayer growth in the cooler portion, thereby producing a heat shadow in the resultant epilayer. Such a heat shadow may interfere with later circuit fabrication in the epilayer, and is undesirable.

Alternatively, one or more contact members may not terminate in a point, but may take some other shape, such as a ring or curved section. For example, the wafer support may include a single ring-shaped contact member supporting the wafer near
its outer edge, a single arm extending from the central hub to support the ring-shaped contact member, and a void adjacent the single arm extending to the bottom of the reaction chamber.

Reaction chamber 56 further includes an inlet 106 and an outlet 108. The inlet is configured to receive a gas mixture from a gas source (not shown) and direct the flow of the gas mixture around wafer 58 to outlet 108. Outlet 108 is configured to transport the gas mixture to an exhaust system (not shown). Typically, the gas mixture includes a source gas containing epilayer semiconductor constituents, such as silicon, gallium, arsenic, and germanium. The gas mixture may also include a dopant gas including a dopant constituent, such as boron, phosphorous, arsenic, or antimony. These semiconductor and dopant constituents are transported to the wafer surface as volatile species suspended in the gas mixture. Typically, the constituents are adsorbed onto the substrate at high temperature and diffuse across the surface to form the epilayer.

Where it is desired to etch material from the wafer 58, wafer support 60, or reaction chamber 56, the gas mixture may also include an etch gas, such as hydrogen chloride. It is also common for the gas mixture to include a carrier gas, such as hydrogen, which does not react with the wafer, but acts as a diluent within the gas mixture.

Inlet 106 and outlet 108 are horizontally disposed on opposite sides of reaction chamber 56, and wafer support 60 is configured to hold wafer 58 intermediate the inlet and the outlet, such that the gas mixture flows from the inlet, around the wafer, and to the outlet. During this gas flow, the gas mixture flows to each of the front side 66 and the back side 68 of the wafer. The wafer may be raised or lowered within the reaction chamber to adjust gas flow around the wafer; for example, the wafer may be raised to increase gas flow to the back side of the wafer. To reach the back side of wafer 58, the gas mixture flows through the voids 70 in wafer support 60.

According to the present invention, a method may be practiced for susceptorless epitaxial growth of a layer of semiconductor material on a semiconductor wafer. The method includes placing wafer 58 within reaction chamber 56 and supporting the wafer directly on a contact member 86 of wafer support 60. The
method further includes heating the wafer to a predetermined temperature without also heating a susceptor. Typically, the heat energy is radiated directly to a front and back side of the wafer.

The radiant energy passes through voids 70 in wafer support 60, shown in Fig. 6, directly to the back side of the wafer. The voids in wafer support 60 enable the heat energy source to heat the wafer without substantial structural interference by a susceptor or the wafer support. In addition, the voids decrease the thermal mass of the wafer support. Therefore, compared to prior reactors with susceptors, the present invention enables the wafer to be heated more directly and quickly.

Reaction chamber 56 is heated by heat energy sources 52, 54 until wafer 58 reaches a predetermined process temperature at which it is desired that epilayer growth occur. The process temperature typically is between 900 and 1200 degrees Celsius. The method may also include positioning a thermocouple 72 proximate wafer 58 to sense the temperature of the reaction chamber adjacent the wafer. To reduce thermal interference with the wafer, the thermocouple typically does not contact the wafer. As shown in Fig. 4, thermocouple 72 may be covered by a cap 74, typically of graphite material. Cap 74 absorbs heat energy and insulates thermocouple 72 such that the thermocouple is not subject to temporary temperature fluctuations caused, for example, by convection due to gas currents in the reaction chamber, and may measure more accurately the temperature adjacent the wafer. The thermocouple is used to control the amount of heat added to the reaction chamber, such that the temperature in the reaction chamber may be precisely controlled.

The method also includes flowing a source gas including semiconductor constituents across the wafer to facilitate epilayer growth on a surface of the wafer.

Source gas is flowed through void 70 to reach the back side of the wafer. The method may also include flowing a dopant gas, etch gas, and/or carrier gas to a front and back side of the wafer, the gases reaching the back side through void 70. Typically, the gases are simultaneously flowed to the front and back side of the wafer. Alternatively, the gases may be flowed alternately to a front side and a back side of the wafer, or flowed only to one of the front or back sides of the wafer.
Over time, deposits from the epilayer growth process build up on the components within reaction chamber 56. Such deposits may contaminate a growing epilayer, and must be removed periodically. The present invention may include removing the contact member from the wafer support and replacing the contact member. Typically, this is accomplished using a contact member as shown in Figs. 7-9. The deposits may also be removed by flowing an etch gas through the reaction chamber.

To distribute heat energy and gases flowing through reaction chamber 56 to wafer 58 evenly, the method may include rotating the wafer within the reaction chamber during growth of the epitaxial layer. The method may also include moving the wafer up and down within the reaction chamber during growth of the epitaxial layer to adjust the heat and/or gas mixture reaching a region of the wafer.

The method may also include deposition of a gettering layer on the back side of the wafer during the epilayer deposition cycle. Gettering is a natural process by which defects in the crystal lattice attract impurities within the semiconductor material. The impurities are attracted to the defects due to the strain the defects create in the crystal lattice. As a result, impurities tend to precipitate around the defects. The method may include intentionally creating defects, or gettering sites, in the crystal lattice to attract contaminants away from the epilayer. For example, the method may include depositing a polysilicon layer on the back surface of the wafer to create strain within the crystal lattice.

The method may also include loading a wafer into the reaction chamber by an understructure, such as spatula 110, 110a, or 110b, shown in Fig. 6. During loading, the wafer is brought into the reaction chamber on the spatula, to a position indicated at 58a in Fig. 3. Wafer support 60 may then be moved up to raise the wafer off of spatula 110, at which time spatula 110 is withdrawn from the reaction chamber. Wafer support 60 then typically is lowered into position for epilayer growth. Mechanical loading of the wafer by such an understructure is less complex and significantly decreases loading time compared with vacuum loading mechanisms employed by reactors with susceptors.
According to the present invention, epitaxial growth may occur in a reactor system without the susceptor 22, Saturn ring 23, or Saturn ring support 28 found on prior reactors. Therefore, the reaction chamber may be heated and cooled more quickly, with less energy, and epilayer growth may be achieved in a shorter cycle time per wafer, resulting in a finished epitaxial wafer of reduced cost. In addition, semiconductor deposition on reactor components and contamination therefrom is significantly reduced. It is believed that lower quantities of source gases are required by the present invention, because incidental deposition on other reactor components is reduced. In addition, the present invention may be used to prevent autodoping during the epilayer growth process, because an epilayer may be deposited on the back side of the wafer. Finally, direct, even heating of the wafer on both sides through the voids in the wafer support reduces thermal strain in the wafer experienced by reactors where heat transfer occurs between the wafer and a susceptor.

**Industrial Applicability**

This invention is applicable to the semiconductor processing industry, and particularly to epitaxial reactor systems for use in growing an epitaxial layer of semiconductor material on a semiconductor wafer.

While the invention has been disclosed in its preferred form, the specific embodiments thereof as disclosed and illustrated herein are not to be considered in a limiting sense as numerous variations are possible. The subject matter of the invention includes all novel and non-obvious combinations and subcombinations of the various elements, features, functions and/or properties disclosed herein. No single feature, function, element or property of the disclosed embodiments is essential. The following claims define certain combinations and subcombinations which are regarded as novel and non-obvious. Other combinations and subcombinations of features, functions, elements and/or properties may be claimed through amendment of the present claims or presentation of new claims in this or a related application. Such claims also are regarded as included within the subject matter of the present invention irrespective of whether they are broader, narrower, or equal in scope to the original claims.
WE CLAIM:

1. A wafer support device to support a semiconductor wafer within a reactor system during epitaxial growth of a semiconductor material onto the wafer, the wafer support device comprising:
   a hub;
   at least three arms extending radially outward from the hub; and
   at least three tips, each tip being associated with a respective arm, and each tip including a point, the point being configured to directly contact the back side of the wafer and to support the wafer in a substantially horizontal orientation within the reactor system.

2. The wafer support device of claim 1, where each tip includes a taper that terminates in the corresponding point.

3. The wafer support device of claim 1, where the tips are removable from the arms.

4. The wafer support device of claim 3, where each arm includes a respective hole and each of the tips is configured to be removably mounted in a corresponding hole.

5. The wafer support device of claim 3, where each arm includes a respective projection and each of the tips is configured to be removably mounted on a corresponding projection.
6. The wafer support device of claim 1, further comprising a shaft mounted to the hub, the shaft being configured to rotate the hub.

7. The wafer support device of claim 1, further comprising a shaft mounted to the hub, the shaft being configured to move the hub up and down.

8. The wafer support device of claim 1, where the hub and arms are quartz.

9. The wafer support device of claim 1, where the tips are carbide.

10. The wafer support device of claim 1, where the tips are quartz.

11. The wafer support device of claim 1, where each tip has a radius of 0.5 mm or less.
12. A reactor system for use in growth of an epitaxial layer of semiconductor material on a semiconductor wafer, the reactor system comprising:
   a reaction chamber including an inlet and an outlet, each of the inlet and outlet being configured to flow a source gas across the reaction chamber;
   a wafer support including a hub, at least three arms extending radially outward from the hub, and at least three tips, each tip being associated with a respective arm, and each tip including a point, the point being configured to directly contact the back side of the wafer and to support the wafer in a substantially horizontal orientation within the reaction chamber; and
   a semiconductor wafer including a front side and a back side, the wafer being positioned substantially horizontally within the reaction chamber intermediate the inlet and the outlet such that the back side rests directly upon the points of the wafer support.
13. A reactor system for use in growth of an epitaxial layer of semiconductor material on a semiconductor wafer, the reactor system comprising:
a reaction chamber including an inlet and an outlet, each of the inlet and outlet being configured to flow a source gas across the reaction chamber;
a wafer support positioned at least partially within the reaction chamber, the wafer support including a contact member coupled to a hub by an arm, and a void adjacent the arm; and
a semiconductor wafer including a front side and a back side, the wafer being positioned substantially horizontally within the reaction chamber intermediate the inlet and the outlet such that the back side rests directly upon the contact member of the wafer support;
where the reaction chamber is configured to direct flow of a source gas substantially horizontally from the inlet to the outlet across the wafer such that the gas flows through the void.

14. The reactor system of claim 13, where the wafer support includes at least three arms extending radially outward from the hub.

15. The reactor system of claim 14, where the wafer support includes at least three tips, each tip being associated with a respective arm, and each tip including a point configured to directly contact the back side of the wafer and to support the wafer in a substantially horizontal orientation within the reaction chamber, and where the contact member comprises at least one of the tips.

16. The reactor system of claim 13, where the contact member is removable from the arm.
17. The reactor system of claim 16, where the arm includes a hole and the contact member is configured to be removably mounted in the hole.

5 18. The reactor system of claim 16, where the arm includes a projection and the contact member is configured to be removably mounted on the projection.

19. The reactor system of claim 13, further comprising a shaft mounted to the hub, the shaft being configured to rotate the hub.

20. The reactor system of claim 13, further comprising a shaft mounted to the hub, the shaft being configured to move the hub up and down.

21. The reactor system of claim 13, where the hub and arm are quartz.

20 22. The reactor system of claim 13, where the contact member is carbide.

23. The reactor system of claim 13, where the contact member is quartz.

24. The reactor system of claim 13, where the contact member includes a point having a radius of 0.5 mm or less.
25. The reactor system of claim 13, further comprising a thermocouple positioned adjacent the wafer and configured to sense a temperature within the reaction chamber adjacent the wafer.

26. A reactor system for use in growth of an epitaxial layer of semiconductor material on a semiconductor wafer, the reactor system comprising:

   a reaction chamber;

   a wafer support positioned at least partially within the reaction chamber, the wafer support including a contact member coupled to a hub by an arm, and a void adjacent the arm;

   a semiconductor wafer including a front side and a back side, the wafer being positioned substantially horizontally within the reaction chamber such that the back side rests directly upon the contact member of the wafer support; and

   a heat energy source positioned below the wafer and configured to radiate heat energy to the wafer through the void in the wafer support.
27. A reactor system for use in growth of an epitaxial layer of semiconductor material on a semiconductor wafer, the reactor system comprising:
   a reaction chamber including an inlet and an outlet, each of the inlet and outlet being configured to flow a source gas across the reaction chamber;
   a wafer support positioned at least partially within the reaction chamber, the wafer support including a contact member coupled to a hub by an arm, and a void adjacent the arm; and
   a semiconductor wafer including a front side and a back side, the wafer being positioned substantially horizontally within the reaction chamber intermediate the inlet and the outlet such that the back side rests directly upon the contact member of the wafer support;
   where the wafer support does not include a susceptor; and
   where the void extends from the back side of the wafer to the bottom of the reaction chamber.

28. A reactor system for use in growth of an epitaxial layer of semiconductor material on a semiconductor wafer, the reactor system comprising:
   a reaction chamber;
   a semiconductor wafer including a back side;
   a wafer support means positioned at least partially within the reaction chamber for supporting the wafer within the reaction chamber without a susceptor; and
   a void extending from the back side of the wafer beyond the wafer support means.
Fig. 1
(PRIOR ART)

SUBSTITUTE SHEET (RULE 26)
INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/12334

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) :C23C 16/00
US CL. :118/730
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
U.S. : 118/730

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
118/725, 728, 729

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EAST 1.1

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>US 4,468,260 A (HIRAMOTO) 28 August 1984, Fig. 1.</td>
<td>1-2, 8 and 10-11</td>
</tr>
<tr>
<td>Y</td>
<td>US 4,533,820 A (SHIMIZU) 06 August 1985, Fig. 2.</td>
<td>1-2, 6-8, 10-15, 19-21 and 23-28</td>
</tr>
<tr>
<td>X</td>
<td>US 4,540,876 A (MCGINTY) 10 September 1985, Figs. 1 and 2.</td>
<td>1-2, 8-8, 10, 12-15, 19-21 and 23-28</td>
</tr>
<tr>
<td>Y</td>
<td>US 4,821,674 A (DEBOER et al) 18 April 1989, Fig. 4.</td>
<td>25</td>
</tr>
<tr>
<td>X</td>
<td>US 5,044,943 A (BOWMAN et al.) 03 September 1991, Figs. 2-5.</td>
<td>13-14, 16-22 and 24-26</td>
</tr>
</tbody>
</table>

[X] Further documents are listed in the continuation of Box C.

T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

A* document defining the general state of the art which is not considered to be of particular relevance

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Date of the actual completion of the international search
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<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
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<td>Y</td>
<td>US 5,421,893 A (PERLOV) 06 June 1995, Fig. 2(a).</td>
<td>6-7 and 19-20</td>
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<td>X</td>
<td>US 5,863,843 A (GREEN et al) 26 January 1999, Figs. 3-7.</td>
<td>1-28</td>
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<td>US 5,803,977 A (TEPMAN et al) 08 September 1998, Figs. 1-3.</td>
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