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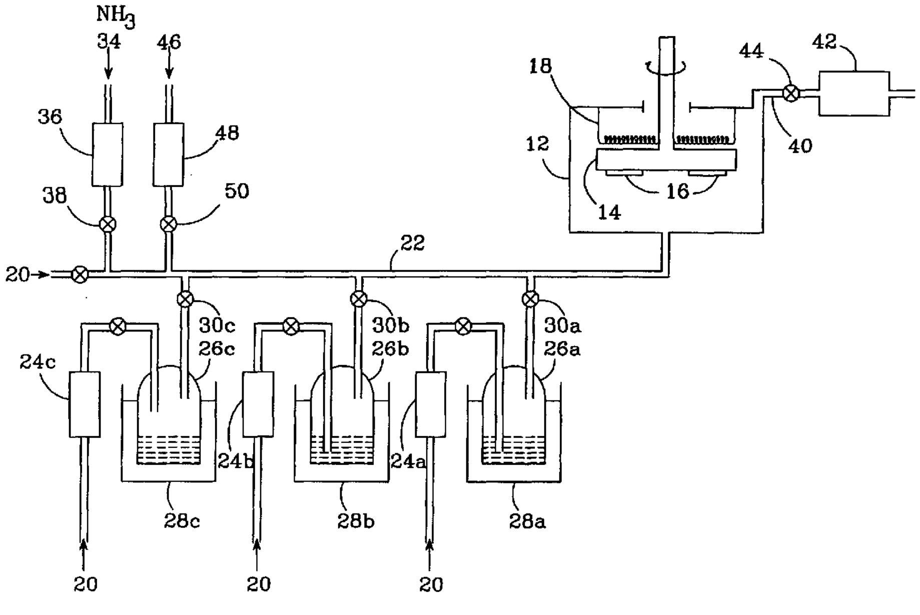

(57) **Abstract:** A semiconductor fabrication reactor (12) comprises a rotatable susceptor (14) mounted to the top of a reactor chamber. One or more wafers (16) are mounted to a surface of the susceptor and the rotation of the susceptor causes the wafers to rotate within the chamber. A heater (18) heats the susceptor and a chamber gas inlet allows semiconductor growth gases into the reactor chamber to deposit semiconductor material on said wafers. A chamber gas outlet (40) is included to allow growth gases to exit the chamber. The inlet is at or below the level of said wafers and the outlet is at or above the level of the wafers.

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APPARATUS FOR INVERTED CVD

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to fabricating semiconductor devices and more particularly to an apparatus for fabricating semiconductor devices using metalorganic chemical vapor deposition (MOCVD).

Description of the Related Art

Numerous semiconductor devices can be fabricated in MOCVD systems using different material systems, with MOCVD systems more recently being used to fabricate Group III nitride based devices. Growth of Group III nitride based semiconductor devices in MOCVD systems is generally described in DenBaars and Keller, *Semiconductors and Semimetals*, Vol. 50, Academic Press Inc., 1997, p. 11-35. One of the concerns in fabricating Group III nitride devices is the ability to produce uniform materials with minimal impurities in the device layers, while providing sharp interfaces between layers. Impurities and poor interfaces between layers can negatively impact device performance and can prevent consistent reproduction of semiconductor devices.

Some conventional multi-wafer MOCVD reactors utilize a rotatable susceptor that is mounted at the bottom of the reactor chamber. [See Emcore Discover and Enterprise Series of the TurboDisc Tools, provided by Emcore Inc.]. Semiconductor wafers are held on the top surface of the susceptor and a heating element is arranged below the susceptor to heat the susceptor and the wafers. Reactant growth gasses enter the reactor to deposit the desired materials on the wafer with the susceptor rotating to provide a more uniform deposition of the materials on the wafer.

One the disadvantages of these conventional MOCVD reactors is that a large and non-uniform boundary layer thickness of hot air can form over the wafers and susceptor as a result of the heating of the susceptor. During growth, heat from the susceptor causes gasses to rise and the boundary layers can extend to the top surface of the reactor chamber. Reactant growth gasses are injected into the reactor chamber, usually through a top inlet. When the lower temperature growth gasses encounter the hot gasses heat convention can occur, which causes turbulence within the reactor. This turbulence can result in non-uniform deposition of materials on the wafer. It is also difficult for the deposition gasses to diffuse through a larger boundary layer and as a result, much of the growth gasses do not deposit on the wafers. This increases the amount of growth gasses necessary to form the desired semiconductor device.

A large boundary layer over a susceptor can also limit the susceptor's speed of rotation. As the rotation speed of a heated susceptor is increased, the boundary layer can cause turbulence that adds to the turbulence from the convection forces of the lower temperature growth gasses. This can lead to further non-uniformity in the device layers.

Another disadvantage of conventional MOCVD reactors is that the growth gasses that do not deposit on the wafers (or susceptor) can deposit on the sidewalls or top surface of the reactor chamber above the susceptor. These deposits can adversely impact the reactor's ability to grow good quality layers. The deposits can react with gasses for subsequent layers and redeposit on the wafers during fabrication. The deposits can be introduced as impurities in the subsequent layers and the deposits can reduce the sharpness between layers. This can ultimately limit the reactor's ability to accurately reproduce the semiconductor devices.

A metal organic vapor phase epitaxy (MOVPE) system for the growth of Group III-V compound semiconductor materials is described in Aria et al., Highly Uniform Growth on a Low-Pressure MOPVE Multiple Wafer System, Journal of Crystal Growth 170, Pgs. 88-91 (1997). The wafers are held in a susceptor and placed facedown (inverted) in the growth chamber, with the flow gasses flowing under the growth surfaces. The susceptor rotates, thereby rotating the wafers to attain a more uniform growth. Gasses are injected into the chamber from one of the sidewalls of the chamber, through a triple flow channel, and the gas exhaust in on the opposite sidewall. Group V species (hydride gasses) and H_2 carrier gas, Group III (organometals) and H_2 carrier gas, and purging gas flow into the reactor through the triple flow channel's upper, middle and lower channels, respectively.

One disadvantage this of system is that because the inlet flow channels are on one chamber side wall and the outlet is on the opposite side wall at about the same height, gas flow is created across the chamber between inlet and outlet. Some of the gasses tend to flow through the chamber without having the opportunity to deposit reactants on the wafers. Also, the leading edges of the wafers experience gasses with the highest concentration of reactants, which results in non-uniform deposition across the wafers.

The fluid flow and mass transport for "chimney" chemical vapor deposition (CVD) reactors is discussed in Holstein, Modeling of Chimney CVD Reactors, Journal of

Crystal Growth 125, Pgs. 311-319 (1992). A chimney reactor has wafers held on heated susceptors (usually two) that are vertically mounted on the interior side walls of the reactor. The intent of the chimney reactor design is to create upward convective gas flow near the susceptor to help promote rapid gas switching for growth of abrupt heterojunctions. A cold carrier gas containing reactants enters at the base of the reactor and flows upward into the heated region.

One of the disadvantages of this design is that asymmetric flow conditions result in the primary gas flow being located near one side of the reactor and reverse flow near the opposite side. This results in different deposition rates at the two susceptors. Also, with upward gas flow, the growth rate uniformity at the leading edge of the susceptor is much greater than at its trailing edge due to depletion of the reactants.

Growth of GaAs based semiconductor devices in an MOCVD reactor is also discussed in Lee et al. <u>MOCVD in Inverted Stagnation Point Flow</u>, Journal of Crystal Growth, Pgs 120-127 (1886). The reactor is based on inverted stagnation point flow geometry where the reactants flow up towards wafers clamped to an inverted heated susceptor. However, this reactor is stagnation flow, where the susceptor does not rotate, which can reduce the uniformity of the device layers.

SUMMARY OF THE INVENTION

The present invention seeks to provide an improved method and apparatus for the fabrication of semiconductor devices, and in particular the fabrication of semiconductor devices in MOCVD reactors. One embodiment of a semiconductor fabrication reactor according to the present invention comprises a rotatable susceptor mounted to the top of a reactor chamber. One or more wafers are mounted to a surface of the susceptor and the rotation of the susceptor causes the wafers to rotate within the chamber. A heater heats the susceptor and a chamber gas inlet allows semiconductor growth gasses into the reactor chamber to deposit semiconductor material on said wafers. The inlet is preferably at or below the level of said wafers. A chamber gas outlet is included to allow growth gasses to exit the chamber. The outlet is preferably at or above the level of the wafers.

Another embodiment according to the invention comprises a semiconductor fabrication system that includes a source of gasses for forming epitaxial layers on wafers and a source of gasses for dopants in said epitaxial layers. A gas line carries the dopant and epitaxial source gasses to a reactor for growing semiconductor devices on wafers, and the source gasses in the gas line are injected into the reactor through a reactor inlet. The reactor comprises an inverted susceptor mounted in a reactor chamber that is capable of rotating. One or more wafers are mounted to a surface of the susceptor, the rotation of the susceptor causing the wafers to rotate within the chamber. A heater heats the susceptor and the source gasses deposit semiconductor material on the wafers. A chamber outlet allows the growth gasses to exit the chamber. In a preferred embodiment, the inlet at or below the level of said wafers and the outlet is above the level of said wafers.

In a preferred embodiment according to the invention, the susceptor has a face down surface facing the bottom of said chamber, and the wafers are mounted to the face down surface. As fully described below, by inverting the susceptor the depth of the boundary layer is reduced, which reduces the turbulence generated when lower temperature growth gasses encounter the boundary layer. The growth gasses can also more easily penetrate the boundary layer and the susceptor can be rotated at a higher rotation rate. This arrangement also helps reduce the level of impurities in the semiconductor material that are introduced from deposits within the reactor chamber.

These and other further features and advantages of the invention will be apparent to those skilled in the art from the following detailed description, taken together with the accompanying drawings, in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a simplified schematic of an embodiment of an MOCVD semiconductor fabrication system according to the present invention;

FIG. 2 is a sectional view of one embodiment of a reactor according to the present invention;

FIG. 3 is a sectional view of another embodiment of a reactor according to the present invention having a central rotation rod gas inlet;

FIG. 4 is a below perspective view of an embodiment of a susceptor according to the present invention that can be used in the reactor in FIG. 3;

FIG. 5 is a sectional view of another embodiment of a reactor according to the present invention having a central bottom gas inlet;

FIG. 6 is a sectional view of another embodiment of a reactor according to the present invention having bottom showerhead gas inlet;

FIG. 7 is a sectional view of another embodiment of a reactor according to the present invention having sidewall gas inlet; and

FIG. 8 is a sectional view of another embodiment of a reactor according to the present invention having a height adjustable susceptor.

DETAILED DESCRIPTION OF THE INVENTION

MOCVD reactors with inverted susceptors according to the present invention can be used in many different semiconductor fabrication systems, but are particularly adapted for use in MOCVD fabrication systems of the type shown in FIG. 1. MOCVD is a nonequilibrium growth technique that relies on vapor transport of precursers and subsequent reactions of Group III alkyls and Group V hydrides in a heated zone. Composition and growth rate are controlled by controlling mass flow rate and dilution of various components of the gas stream to the MOCVD reactor.

Organometallic Group III growth gas sources are either liquids such as trimethylgallium (TMGa) and trimethylaluminum (TMAl), or solids such as trimethylindium (TMIn). The organometallic sources are stored in bubblers through which a carrier gas (typically hydrogen) flows. The bubbler temperature controls the vapor pressure over source material. Carrier gas will saturate with vapor from the organometallic source and transport vapor to the heated substrate.

Group V growth gas sources are most commonly gaseous hydrides, for example NH_3 for nitride growth. Dopant materials can be metal organic precursers [diethylzine (DEZn), cyclopenin dienyl magnesium (Cp_2Mg)j or hydrides (silane or disilane). Growth gasses and dopants are supplied to the reactor and are deposited as epitaxial layers on a substrate or wafer. One or more wafers are held on a structure of graphite called a susceptor that can be heated by a radio frequency (RF) coil, resistance heated, or radiantly heated by a strip heater, which in turn heats the wafers.

The MOCVD semiconductor fabrication system 10 comprises a reactor chamber 12 having a susceptor 14 that is mounted to the top of the chamber 12 and is inverted. The susceptor 14 can hold a plurality of wafers 16 that can be made of many different materials such as sapphire, silicon (Si), silicon carbide (SiC), aluminum gallium nitride (AlGaN), gallium arsenide (GaAs). For Group III nitride based semiconductor devices a preferred wafer is made of SiC because it has a much closer crystal lattice match to Group III nitrides compared to other materials, which results in Group III nitride films of higher quality. SiC also has a very high thermal conductivity so that the total output power of Group III nitride devices on SiC is not limited by the thermal dissipation of the wafer. The availability of semi insulating SiC wafers also provides the capacity for device isolation and reduced parasitic capacitance that make commercial devices possible. SiC substrates are available from Cree, Inc., of Durham, North Carolina and methods for producing them are set forth in the scientific literature as well as in a U.S. Patents, Nos. Re. 34,861; 4,946,547; and 5,200,022.

During growth, the susceptor 14 is heated by heater 18 to maintain wafers 16 at a predetermined temperature. The temperature is typically between 400 and 1200 degrees centigrade (°C), but can be higher or lower depending on the type of growth desired. The heater 18 can be any of the heating devices listed above, but is usually a radio frequency (RF) or resistance coil.

A hydrogen or nitrogen carrier gas 20 is supplied to a gas line 22. The carrier gas 20 is also supplied through mass flow controllers 24a-c to respective bubblers 26a-c. Bubbler 26a can have an organometallic Group III source as described above. Bubblers 26b and 26c may also contain a similar organometallic compound to be able to grow an alloy of a Group III compound. The bubblers 26a-c are typically maintained at a predetermined temperature by constant temperature baths 28a-c to ensure a constant vapor pressure of the organometallic compound before it is carried to the reactor chamber 12 by the carrier gas 20.

The carrier gas 20 which passes through bubblers 28a-c is mixed with the carrier gas 20 flowing within the gas line 22 by opening the desired combination of valves 30a-c. The mixed gas is then introduced into the reactor chamber 12 through a gas inlet port 32, which can be located at different locations on the reactor, but in the system 10 is located at the bottom of the chamber 12.

A nitrogen containing gas 34 such as ammonia is supplied to the gas line 22 through a mass flow controller 36 and the flow of nitrogen containing gas is controlled by valve 38. If the carrier gas 20 is mixed with the nitrogen containing gas 34, and the organometallic vapor within the gas line 22 is introduced into the reactor chamber 12, the elements are present to grow gallium nitride on the substrates 16 through thermal decomposition of the molecules in the organometallic and nitrogen containing gas.

To dope alloys of gallium nitride on the wafers 16, one of the bubblers 26a-c not being used for the organometallic compounds, can be used for a dopant material. Many different doping materials can be used such as beryllium, calcium, zinc, or carbon, with preferred materials being magnesium (Mg) or silicon (Si). Bubbler 26b or 26c can be used for an alloy material such as boron, aluminum, indium, phosphorous, arsenic or other materials. Once the dopant and/or alloy are selected and the appropriate valve 30a-c is opened to allow the dopant to flow into gas line 22 with the organometallic and nitrogen containing gas 34, the growth of the doped layer of gallium nitride can take place on substrates 16.

The gas within the reactor chamber 12 can be purged through a gas purge line 40 connected to a pump 42 operable under hydraulic pressure. Further, a purge valve 44 allows gas pressure to build up or be bled off from the reactor chamber 12.

The growth process is typically stopped by shutting off the organometallic and dopant sources by closing valves 30a-c, and keeping the nitrogen containing gas 36 and the carrier gas 20 flowing. Alternatively, the reactor chamber 12 can be purged with a gas 46 that can be controlled through a mass flow controller 48 and valve 50. The purge is aided by opening valve 44 to allow the pump 42 to evacuate the reaction chamber 12 of excess growth gasses. Typically, the purge gas 46 is hydrogen, but can be other gasses. Turning off power to the heater 18 then cools the substrates 16.

FIG. 2 shows one embodiment of a MOCVD reactor 60 in accordance with the present invention. The reactor 60 can be used to fabricate many different semiconductor devices from different material systems, but is particularly applicable to fabricating devices from the Group III nitride material system and its alloys, in an MOCVD fabrication system.

The reactor 60 comprises a reactor chamber 62, with a susceptor 64 that is inverted and mounted from the reactor's top surface 66. The susceptor 64 can be made of many heat conductive materials, with a suitable material being graphite. Semiconductor wafers 68 are mounted on the susceptor's face down surface 70 that faces the chamber's bottom surface 72, with typical susceptors capable of holding approximately six three inch wafers and up to eighteen two inch wafers. The wafers can be held to the susceptor surface 70 by many different mechanisms including, but not limited to, mounting faceplates, clamps, clips, adhesives, tape, etc.

The susceptor 64 is held within the reactor chamber 60 by a rotation rod 74 that can be rotated so that the susceptor 64 is also rotated. The susceptor is heated by a heating element 80 that is arranged between the susceptor 64 and the chamber's top surface. The heater 80 can be any of the heating devices listed above, but is usually a radio frequency (RF) or resistance coil. When the heater 80 heats the susceptor 64, a hot gas boundary layer 82 forms over the susceptor surface 70 and the wafers 68. During growth of semiconductor material on the wafers 68, the growth gasses can enter the chamber 62 in many different ways and through different walls of the chamber 62.

By inverting the susceptor, the depth of the boundary layer 82 is reduced compared to conventional reactor chambers that have a susceptor at the bottom. As the susceptor 64 is heated and generates hot gas, the heated gas rises. Accordingly, the boundary layer 82 is compressed against the susceptor 64 and wafers 68 by the rising of the hot gas. The reduced boundary layer height reduces the turbulence generated when lower temperature growth gasses encounter the boundary layer 82, which allows for more uniform deposition of materials on the wafers 68. The growth gasses can also more easily penetrate the boundary layer 82 and as a result, more of the growth gasses deposit on the wafers 68. This decreases the amount of deposition gasses necessary to form the desired semiconductor device.

The reduced boundary layer also reduces gas convection that can occur when the susceptor 64 rotates. As a result, the susceptor 64 can be rotated much faster than conventionally arranged susceptors. In the reactor 10, the susceptor can be rotated above 100 revolutions per minute (rpm) and up to several thousand rpm.

The reduced boundary layer 82 also allows the deposition gasses to deposit on the wafers 68 under increased reactor chamber pressure to further facilitate efficient fabrication. Depending on the device being fabricated, the pressure can be below 1/8 of an atmosphere to more that 10 atmospheres.

Another advantage of the inverted susceptor arrangement is that most of the growth gasses that do not deposit on the wafers rise past the susceptor 64 toward the top of the chamber 62. These gasses can form deposits 84 on the side walls and top surface of the chamber 62 behind the susceptor. These deposits are less likely to interact with subsequent growth gasses to introduce impurities into the material deposited on the wafers 68 because the growth gasses will not encounter these deposits until they are past the wafers. That is, the gasses encounter these impurities when they are past the point when they are depositing reactants on the wafers. Gasses that do not deposit on the wafers or reactor walls can exit the chamber through a top gas outlet, although the outlet could at different locations on the chamber.

FIG. 3 shows an embodiment of an MOCVD reactor 90 in accordance with the present invention that is similar to the reactor 60 in FIG. 2. The reactor has a rotation rod 92 that is hollow so that deposition gasses can enter the reactor chamber 94 through the rotation rod 92.

FIG. 4 shows a susceptor 96 that can be used in reactor 90, which includes a central gas inlet 98 that allows gas from the rotation rod 92 to enter the reactor chamber 94 through the susceptor 96. As the susceptor 96 rotates, the gasses from the inlet are drawn to the susceptor's perimeter and along the way, some of the growth gasses deposit on the wafers 100. Gasses that do not deposit on the wafers, pass off the edge of the susceptor 96 and are drawn toward the chamber's top surface 102. Like above, these gasses can form deposits 106 on the inside of the chamber's sidewalls 108a, 108b and inside of the chamber's top surface 102, that are downstream and behind the susceptor 96. These deposits are less likely to adversely effect the fabrication of subsequent layers as described above. Gasses can exit the reactor chamber 94 through a gas outlet 110 that is preferably at the top of the reactor chamber, which promotes flow of the gasses past the wafers and then to the top of the chamber.

FIG. 5 shows another embodiment of an MOCVD reactor 120 in accordance with the invention, where the growth gasses enter the chamber 122 through a central bottom inlet 124 that is directed toward the wafers 126 on the rotating susceptor 128. The growth gasses rise toward the susceptor 128 where gasses are deposited on the wafers 126. Like the embodiment in FIG. 3, any gasses that do not deposit on the wafers 126 are drawn past the susceptor 128 where they can form deposits 130 on the inside of the chamber's sidewalls 132a, 132b and inside of the chamber's top surface 134. The reactor also has a top gas outlet 136.

FIG. 6, shows another embodiment of an MOCVD reactor 140 in accordance with the present invention, where the growth gasses enter the reactor chamber 142 through a bottom "showerhead" inlet 144. The inlet 144 has multiple boreholes 145 for the growth gasses to pass into the chamber where they rise toward the wafers 146 on the rotating susceptor 148. The bore-holes 145 in the inlet 144 provide for a more uniform application of the growth gasses across the susceptor 148, which provides for a more uniform deposition of materials on the wafers 146. Like above, the gasses that do not deposit on the wafers are drawn downstream and if they do not deposit on the walls of the reactor chamber 142, they can exit the chamber through the top outlet 149.

FIG. 7 shows another embodiment of an MOCVD reactor 150 in accordance with the present invention, where the deposition gasses enter the reactor chamber 152 through a sidewall inlet 154. Like above, the gasses that do not deposit on the wafers 156 on the rotating susceptor 158 are drawn downstream where they can form deposits 159 on the inside of the reactor's walls. The reactor can also have a top gas outlet 160, which is arranged so that the gasses pass from the inlet 154 toward the top of the chamber 152. The growth gasses rise toward the susceptor 158 where semiconductor material can be deposited on the wafers 156.

FIG. 8 shows still another embodiment of an MOCVD reactor 170 in accordance with the present invention, that includes a reactor chamber 171, rotating susceptor 172, wafers 174 on the susceptor, and a showerhead gas inlet 175, all of which are similar those in reactor 140 of FIG. 6. In most respects, the reactor 170 operates in the same way as the reactor 140 in FIG. 6. However, in reactor 170 the susceptor 172 is mounted to the reactor's top surface 176 by a rod 178 that is movable in directions shown be arrows 177a, 177b, to adjust the distance between the showerhead inlet 175 and the susceptor 172. This adjustment can vary the concentration of reactants in the growth gasses that react with the wafers 174, to vary the semiconductor growth conditions and rate.

As further shown in FIG. 8 the susceptor 172 can be further adjusted in the direction of arrows 178a, 178b to vary the angle between the susceptor 172 and the gas inlet 175. Similarly, the angle of the gas inlet 175 can be adjusted in the direction of arrows 179a, 179b to also adjust the angle between the susceptor 172 and the inlet 175. These adjustments can also vary the semiconductor grown conditions and rate on the wafers 174. The movable susceptor arrangement and angle adjustable susceptor and inlet arrangement can also be used in reactors 60, 120, 150, above that have gas inlets through the susceptor, a bottom inlet and a side inlet, respectively. The reactors can include only one or all of these adjustment options.

Although the present invention has been described in considerable detail with reference to certain preferred configurations thereof, other versions are possible. Many different gas inlets, gas outlets and susceptors can be used. The gas inlets and outlets can be arranged in many different locations. The reactor according to the invention can be used to grow many different semiconductor devices from many different material systems, in many different semiconductor fabrication systems. Therefore, the spirit and scope of the invention should not be limited to the preferred versions in the specification above or in the claims below.

WE CLAIM:

1. A semiconductor fabrication reactor, comprising:

a rotatable susceptor mounted to the top of a reactor chamber;

one or more wafers mounted to a surface of said susceptor, the rotation of said susceptor causing said wafers to rotate within said chamber;

a heater to heat said susceptor;

a chamber gas inlet to allow semiconductor growth gasses into said reactor chamber to deposit semiconductor material on said wafers, said inlet at or below the level of said wafers; and

a chamber gas outlet at or above the level of said wafers.

2. The reactor chamber of claim 1, wherein said susceptor has a face down surface facing the bottom of said chamber, said wafers mounted to said face down surface.

3. The reactor of claim 1, wherein said chamber gas inlet is through the bottom of said reactor chamber.

4. The reactor of claim 1, wherein said chamber gas inlet is a single inlet through the approximate center of the bottom of said chamber.

5. The reactor of claim 1, wherein said chamber gas inlet is a showerhead inlet through the bottom of said chamber, said showerhead inlet having a plurality of boreholes to allow said growth gasses into said chamber.

6. The reactor of claim 1, further comprising a rotation rod connected to the top of said chamber, said susceptor attached to said rotation rod, the rotation of said rotation rod causing said susceptor to rotate in said chamber.

7. The reactor of claim 6, wherein said rod is hollow and wherein a surface of said susceptor has a central inlet in alignment with said rod, said growth gasses entering said chamber through said rod and central inlet.

8. The reactor of claim 1, wherein said chamber gas inlet is through a sidewall of said reactor chamber.

9. The reactor of claim 1, wherein said susceptor can be moved up and down to vary the distance between said inlet and said susceptor.

10. The reactor of claim 1, wherein the angle of said susceptor can be adjusted to adjust the angle between said inlet and said susceptor.

11. The reactor of claim 1, wherein the angle of said inlet can be adjusted to adjust the angle between said inlet and said susceptor.

12. A semiconductor fabrication system, comprising:

a source of gasses for forming epitaxial layers on wafers;

a source of gasses for dopants in said epitaxial layers;

a gas line for carrying said dopant and epitaxial source gasses;

a reactor for growing semiconductor devices on wafers, said reactor comprising;

an inverted susceptor mounted in a reactor chamber, said susceptor capable of rotating and said source gasses in said gas line injected into said reactor chamber through a reactor inlet;

one or more wafers mounted to a surface of said susceptor, the rotation of said susceptor causing said wafers to rotate within said chamber;

a heater to heat said susceptor, said source gasses depositing semiconductor material on said wafers, said inlet at or below the level of said wafers; and

a chamber gas outlet at or above the level of said wafers.

13. The system of claim 12, wherein said susceptor has a face down surface facing the bottom of said chamber, said wafers mounted to said face down surface.

14. The system of claim 12, wherein said reactor inlet is a single inlet through the bottom of said chamber.

15. The system of claim 12, wherein said reactor inlet is a showerhead inlet through the bottom of said chamber, said showerhead inlet having a plurality of boreholes to allow said growth gasses into said chamber.

16. The system of claim 12, further comprising a rotation rod connected to the top of said reactor chamber, said susceptor attached to said rotation rod, the rotation of said rotation rod causing said susceptor to rotate in said chamber.

17. The system of claim 16, wherein said rod is hollow and wherein a surface of said susceptor has a central inlet in alignment with said rod, said growth gasses entering said chamber through said rod and central inlet.

18. The system of claim 12, wherein said reactor inlet is through a sidewall of said reactor chamber.

19. The system of claim 12, wherein said susceptor can be moved up and down to vary the distance between said inlet and said susceptor.

20. The system of claim 12, wherein the angle of said susceptor can be adjusted to adjust the angle between said inlet and said susceptor.

21. The system of claim 12, wherein the angle of said inlet can be adjusted to adjust the angle between said inlet and said susceptor.

22. A metalorganic chemical vapor deposition (MOCVD) semiconductor fabrication reactor, comprising:

a susceptor mounted within an MOCVD reactor chamber;

one or more wafers mounted to a surface of said susceptor;

a means for causing said susceptor to rotate, the rotation of said susceptor causing the wafers to rotate;

a means for heating said susceptor, said susceptor arranged within said chamber so that the boundary layer caused by the heating of said susceptor is compressed;

an inlet means for semiconductor growth gasses to enter said reactor chamber to deposit semiconductor material on said wafers; and

an outlet means at or above the level of said wafers, for growth gasses to exit said chamber.

23. The reactor of claim 22, wherein said inlet means comprises a single inlet through the bottom of said chamber.

24. The reactor of claim 22, wherein said inlet means comprises a showerhead inlet through the bottom of said chamber, said showerhead inlet having a plurality of boreholes to allow said growth gasses into said chamber.

25. The reactor of claim 22, wherein said susceptor is mounted within said reactor by a hollow rotatable rod, the rotation of said rod causing said susceptor to rotate, said inlet means comprising an inlet in said susceptor in alignment with said rod, said growth gasses entering said reactor through said rod and susceptor inlet.

26. The reactor of claim 22, wherein said susceptor can be moved up and down and tilted side to side to vary the conditions for said deposition of semiconductor materials from said growth gasses.

27. The reactor of claim 12, wherein said inlet can be tilted side to side to vary the conditions for the said deposition of semiconductor materials from said growth gasses.

28. The reactor of claim 12, wherein said inlet means is at or below said wafers and said outlet means is at

or above said wafers.

29. A metalorganic chemical vapor deposition (MOCVD) semiconductor fabrication system, comprising:

a source of gasses for forming epitaxial layers on wafers;

a source of gasses for dopants in said epitaxial layers;

an MOCVD reactor for growing semiconductor devices on wafers, said reactor comprising a reactor chamber, said source gasses injected into said chamber through an inlet, said reactor further comprising:

an inverted susceptor mounted in said chamber, said susceptor capable of rotating;

one or more wafers mounted to a surface of said susceptor, the rotation of said susceptor causing said wafers to rotate within said chamber;

a heater to heat said susceptor, said source gasses depositing semiconductor materials on said wafers; and

a gas outlet to allow said growth gasses to exit said wafers.

30. The system of claim 29, wherein said reactor inlet is a showerhead inlet through the bottom of said chamber, said showerhead inlet having a plurality of boreholes to allow said growth gasses into said chamber.

31. The system of claim 29, wherein said susceptor can be moved up and down to vary the distance between said inlet and said susceptor.

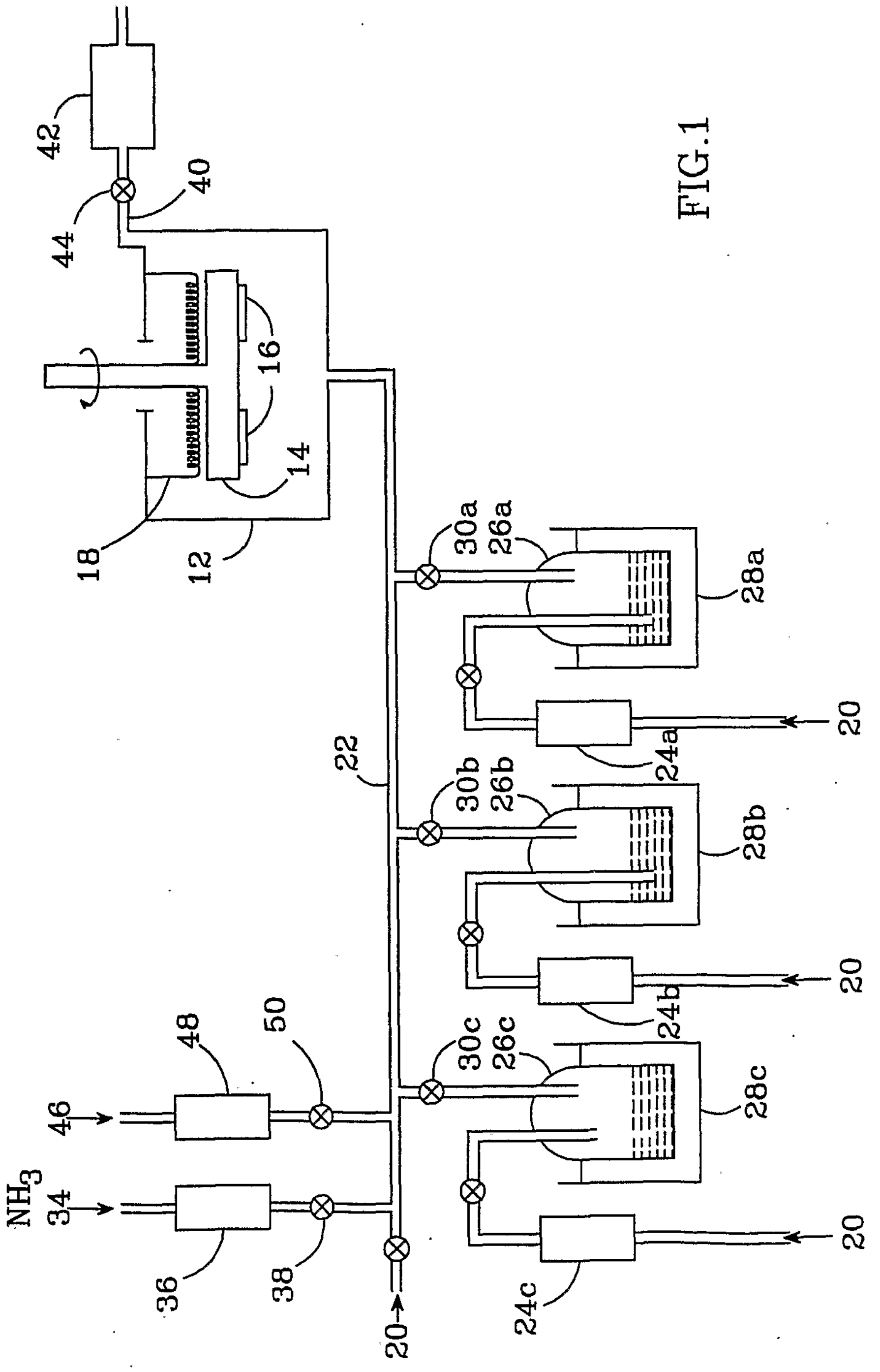
42
44
40
16
14
18
12
22
30a
26a
28a
24a
20
30b
26b
28b
24b
20
30c
26c
28c
24c
20
48
50
46
NH_3
34
36
38
20

FIG.1

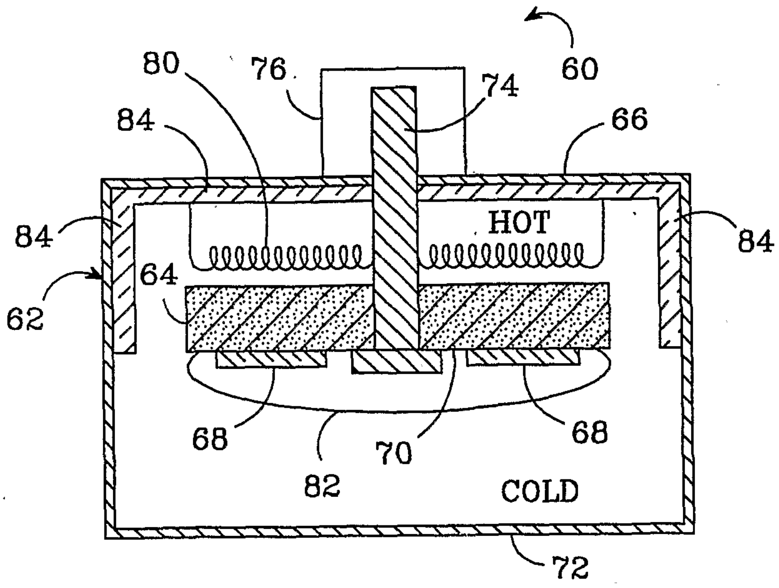
60
80
76
74
84
66
HOT
84
84
64
62
68
70
68
82
COLD
72

FIG.2

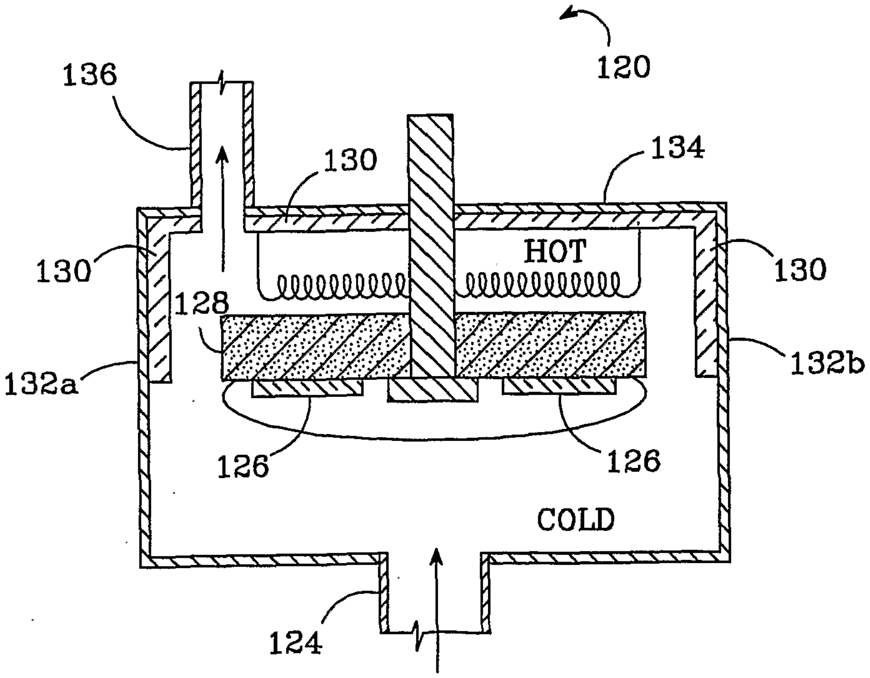
120
136
130
134
130
HOT
130
128
132a
132b
126
126
COLD
124

FIG.5

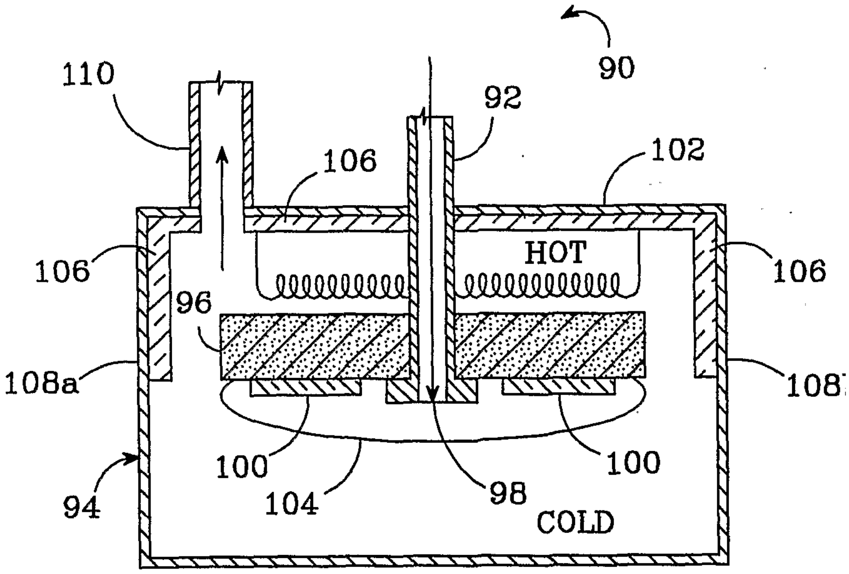
90
110
92
102
106
106
HOT
106
96
108a
108
100
100
104
98
94
COLD

FIG.3

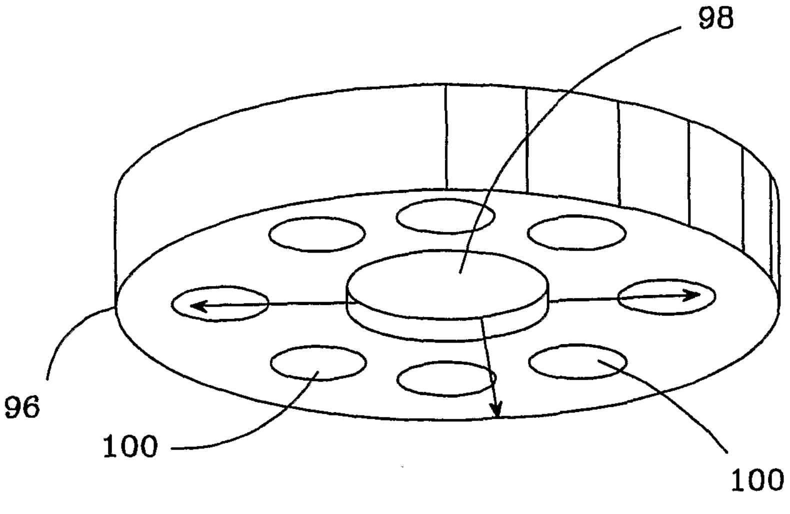
98
96
100
100

FIG.4

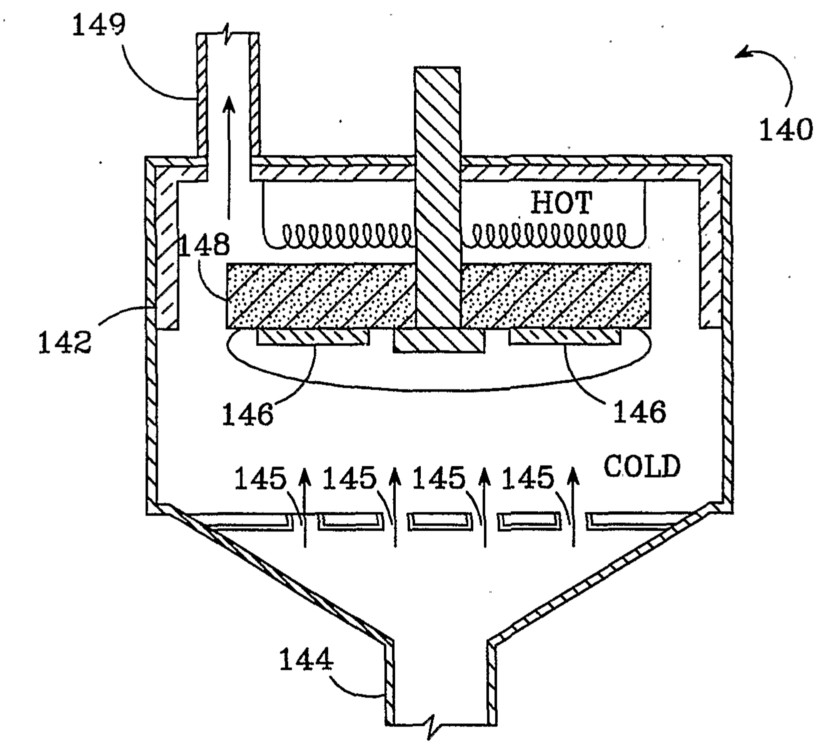
149
140
HOT
148
142
146
146
145
145
145
145
COLD
144

FIG.6

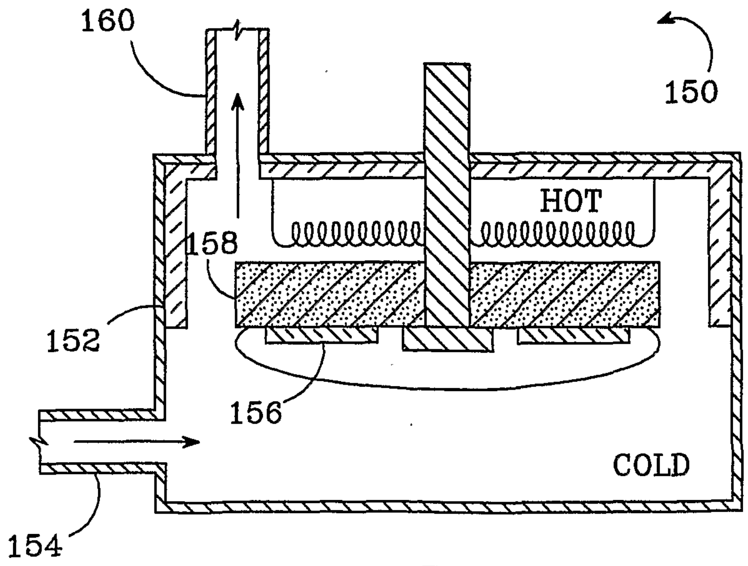
160
150
HOT
158
152
156
COLD
154

FIG.7

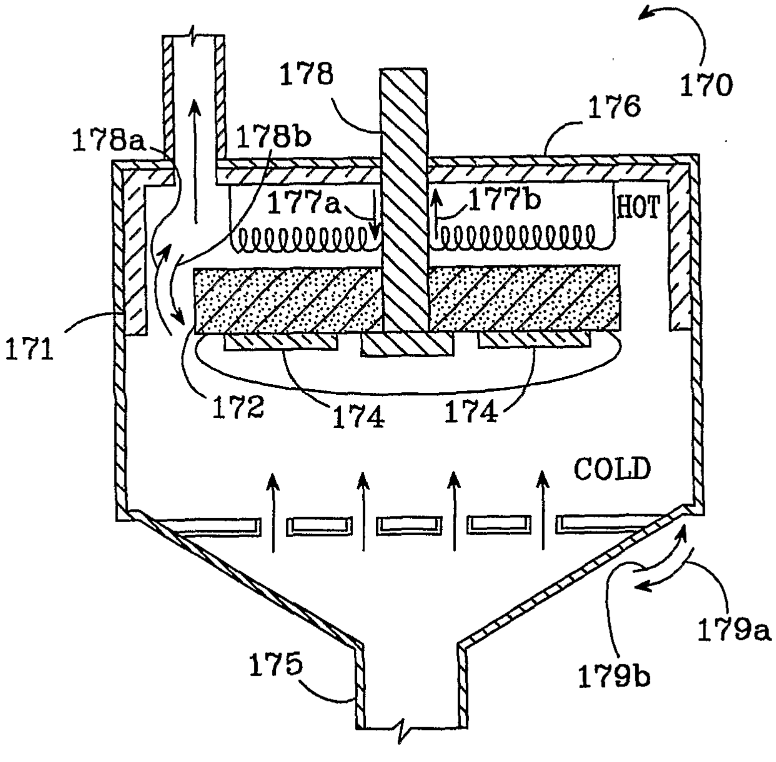
170
178
176
178a
178b
177a
177b
HOT
171
172
174
174
COLD
175
179b
179a

FIG.8

INTERNATIONAL SEARCH REPORT

Internatio[illegible]pplication No
PCT/US 02/30960

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 C23C16/455 C30B25/14

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)
IPC 7 C23C C30B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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

PAJ, WPI Data, EPO-Internal, IBM-TDB

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 016, no. 394 (C-0976), 21 August 1992 (1992-08-21) & JP 04 128379 A (MITSUBISHI ELECTRIC CORP), 28 April 1992 (1992-04-28)	1,2,5,6, 12,13, 15,16, 22,24, 28-30
Y	abstract ---	4,7, 9-11,14, 17, 19-21, 23, 25-27,31
X	EP 0 811 702 A (SIEMENS AG) 10 December 1997 (1997-12-10) figure 5 ---	1-3,12, 13,15, 22,24, 28-30

-/--

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search
24 February 2003

Date of mailing of the international search report
03/03/2003

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Authorized officer
Ekhult, H

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	ARAI T ET AL: "Highly uniform growth in a low-pressure MOVPE multiple wafer system" JOURNAL OF CRYSTAL GROWTH, NORTH-HOLLAND PUBLISHING CO. AMSTERDAM, NL, vol. 170, no. 1-4, 1997, pages 88-91, XP004087082 ISSN: 0022-0248 cited in the application figure 1	1,2,6,8, 11-13, 16,18, 22,28,29
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Y	US 6 239 043 B1 (LAI YEONG-CHIH) 29 May 2001 (2001-05-29) column 5, line 12 - line 52; figure 4	9-11, 19-21, 26,27,31
Y	FR 1 462 335 A (PHILIPS NV) 15 April 1966 (1966-04-15) figure 1	4,14,23
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Inf[illegible]ation on patent family members

Internatio[illegible]Application No

PCT/US 02/30960

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