



US 20030111961A1

(19) **United States**

(12) **Patent Application Publication**

**Katz et al.**

(10) **Pub. No.: US 2003/0111961 A1**

(43) **Pub. Date: Jun. 19, 2003**

(54) **GAS DISTRIBUTION PLATE ELECTRODE  
FOR A PLASMA REACTOR**

**Publication Classification**

(75) Inventors: **Dan Katz**, Agoura Hills, CA (US);  
**Douglas A. Buchberger JR.**,  
Livermore, CA (US); **Yan Ye**, Saratoga,  
CA (US); **Robert B. Hagen**, Newark,  
CA (US); **Xiaoye Zhao**, Mountain  
View, CA (US); **Ananda H. Kumar**,  
Fremont, CA (US); **Kang-Lie Chiang**,  
San Jose, CA (US); **Hamid**  
**Noorbakhsh**, Fremont, CA (US);  
**Shiang-Bau Wang**, Hsinchu (TW)

(51) **Int. Cl.<sup>7</sup> ..... H01J 7/24**

(52) **U.S. Cl. .... 315/111.21; 315/111.71**

(57) **ABSTRACT**

The invention is embodied in a plasma reactor for processing a semiconductor wafer, the reactor having a gas distribution plate including a front plate in the chamber and a back plate on an external side of the front plate, the gas distribution plate comprising a gas manifold adjacent the back plate, the back and front plates bonded together and forming an assembly. The assembly includes an array of holes through the front plate and communicating with the chamber, at least one gas flow-controlling orifice through the back plate and communicating between the manifold and at least one of the holes, the orifice having a diameter that determines gas flow rate to the at least one hole. In addition, an array of pucks is at least generally congruent with the array of holes and disposed within respective ones of the holes to define annular gas passages for gas flow through the front plate into the chamber, each of the annular gas passages being non-aligned with the orifice.

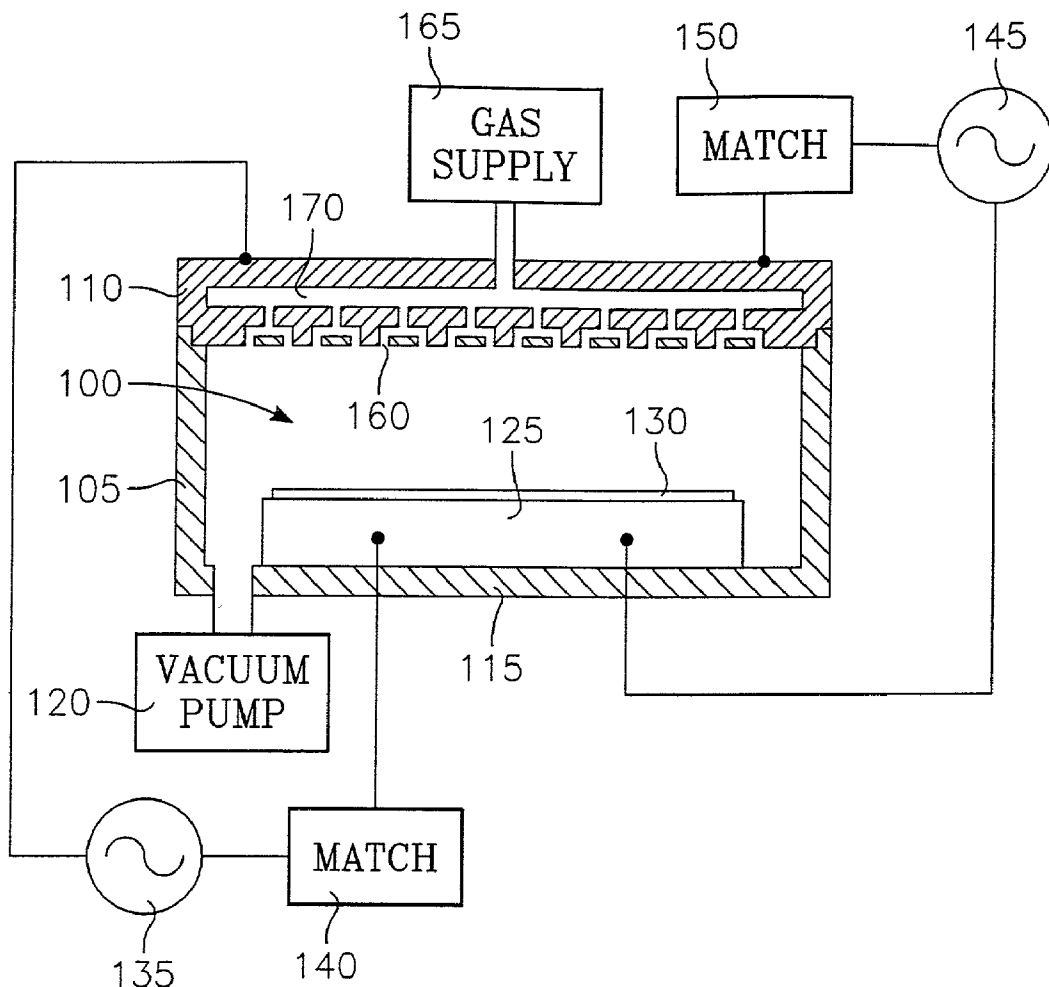
Correspondence Address:

**APPLIED MATERIALS, INC.**  
**2881 SCOTT BLVD. M/S 2061**  
**SANTA CLARA, CA 95050 (US)**

(73) Assignee: **Applied Materials, Inc.**

(21) Appl. No.: **10/027,732**

(22) Filed: **Dec. 19, 2001**



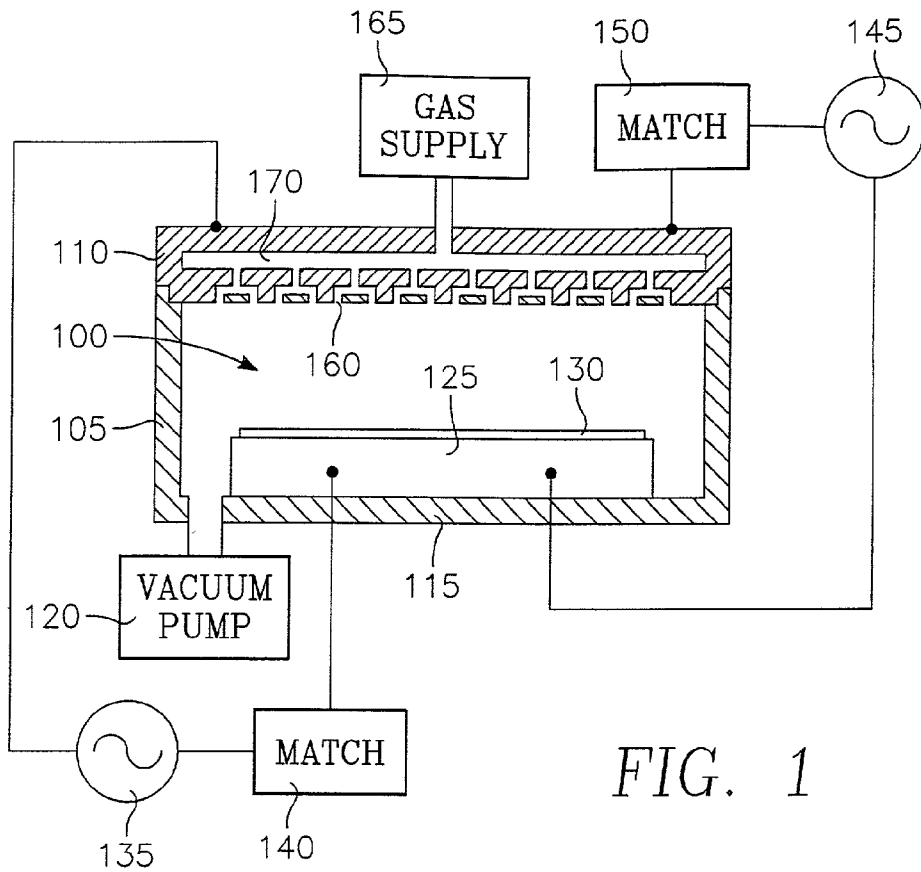


FIG. 1

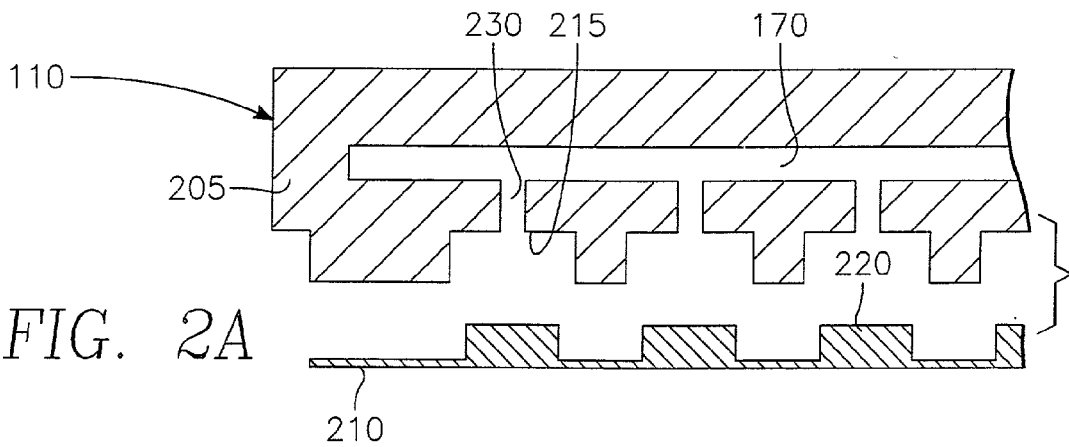


FIG. 2A

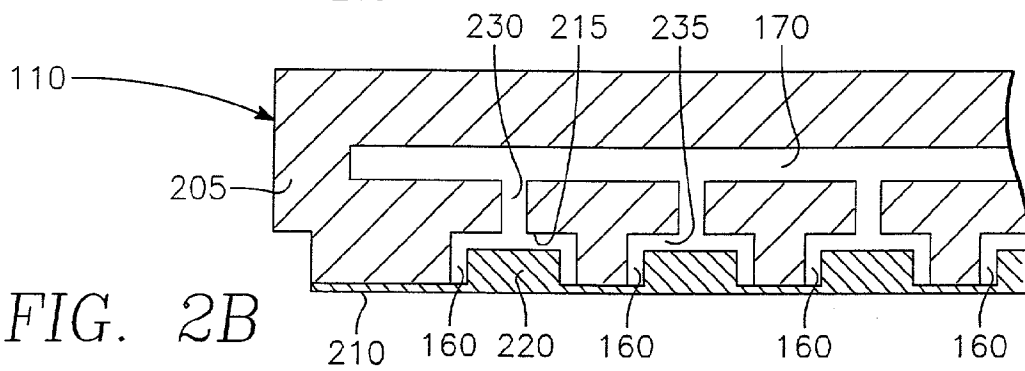


FIG. 2B

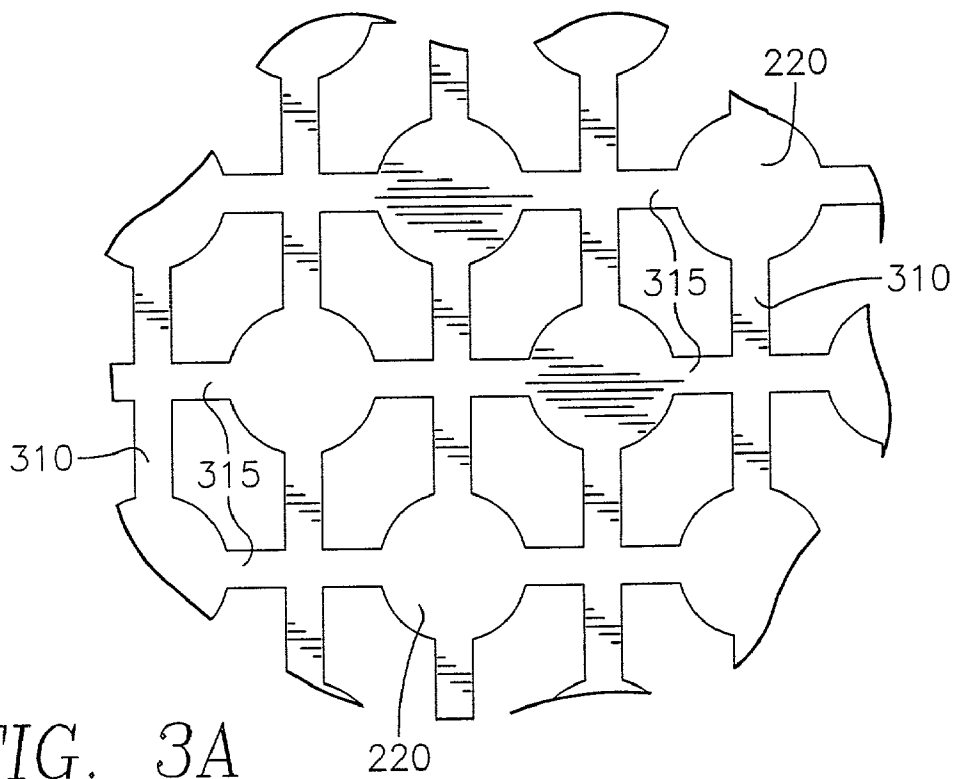


FIG. 3A

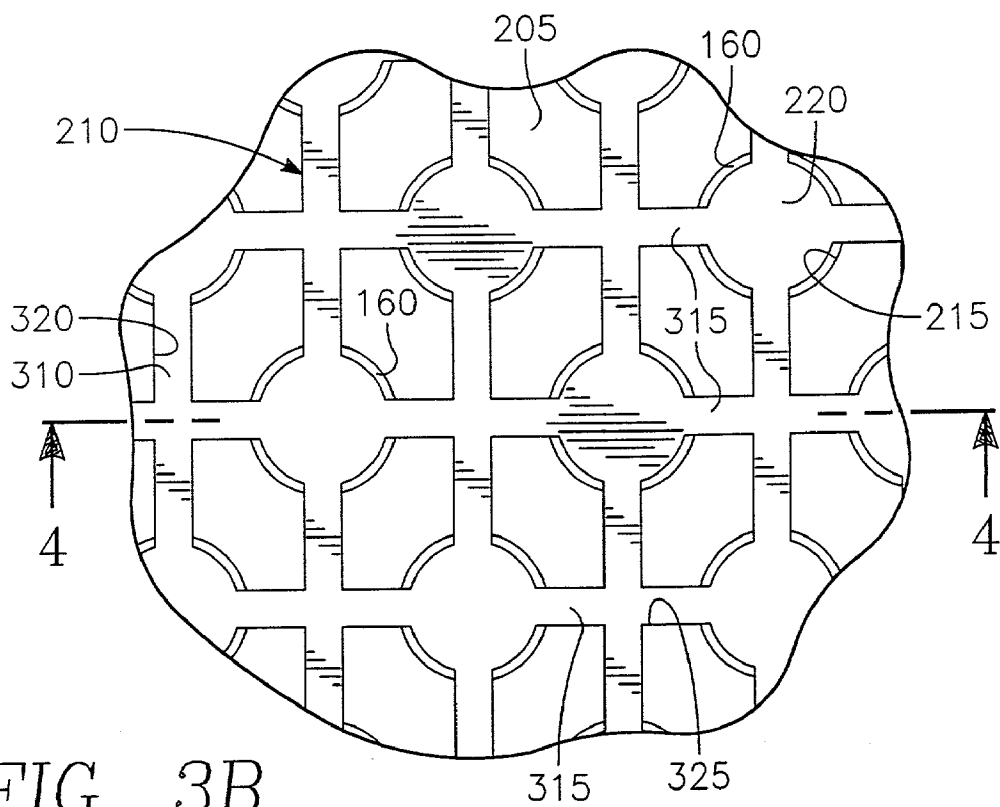
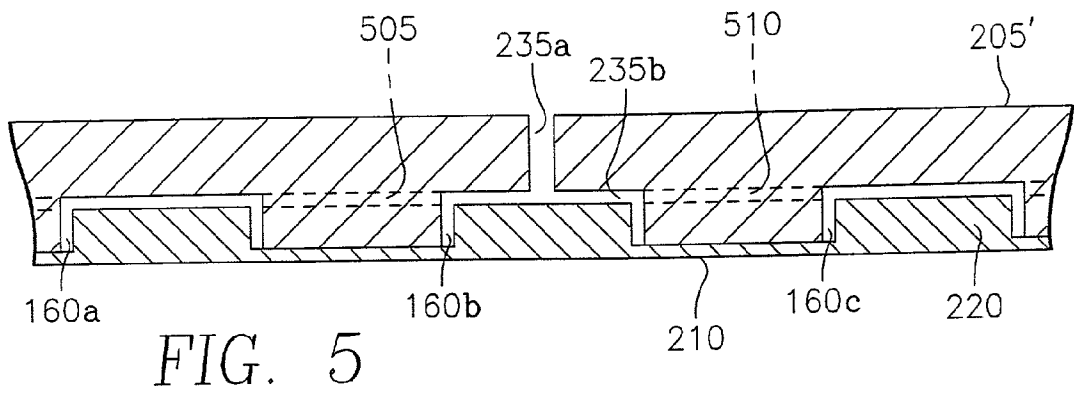
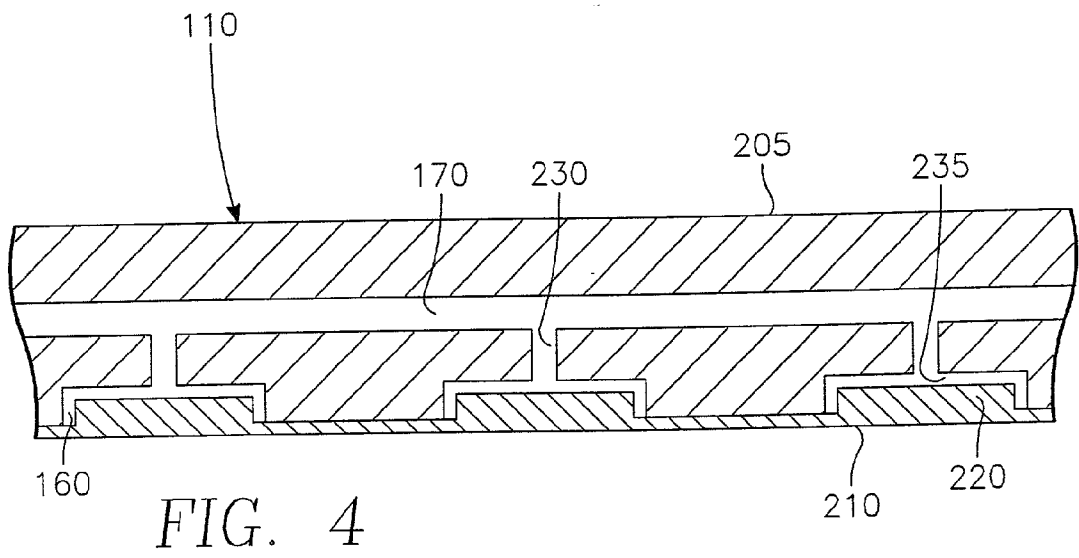


FIG. 3B



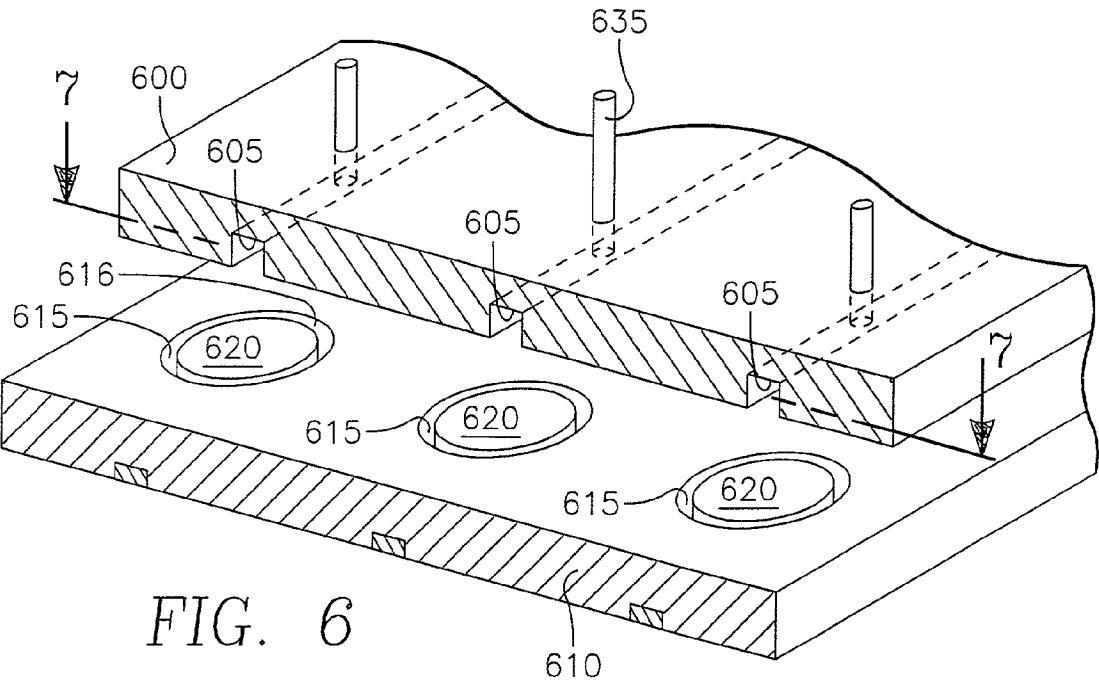


FIG. 6

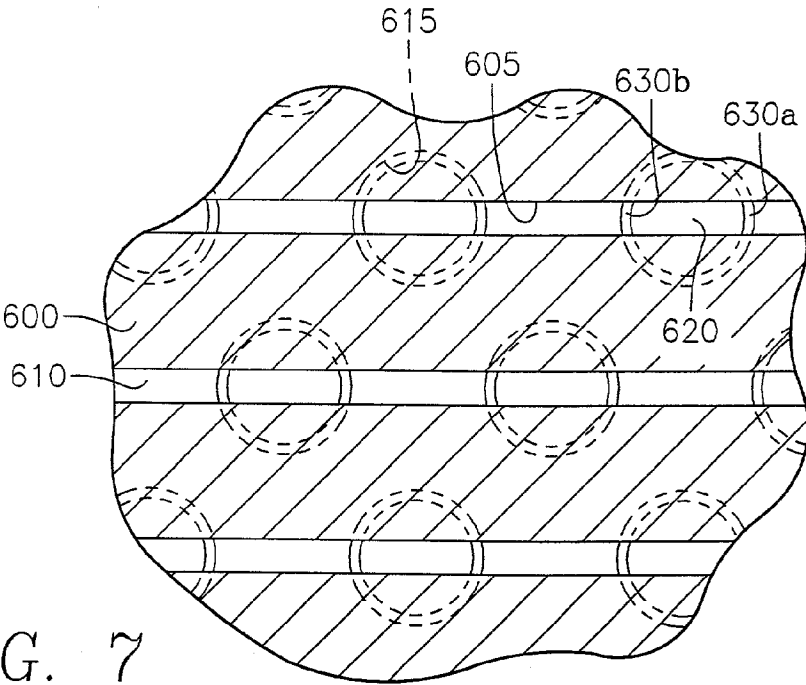


FIG. 7

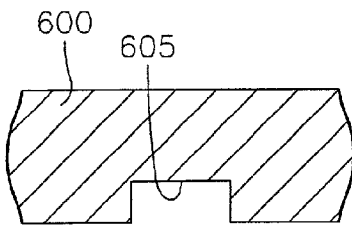


FIG. 8A

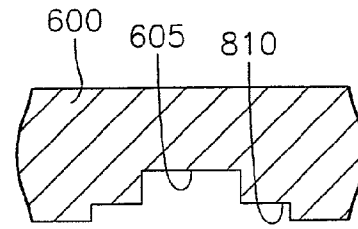


FIG. 9A

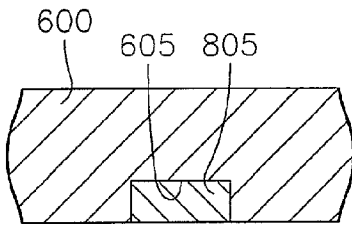


FIG. 8B

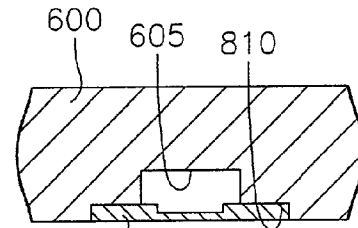


FIG. 9B

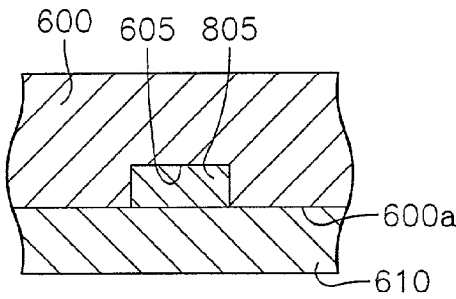


FIG. 8C

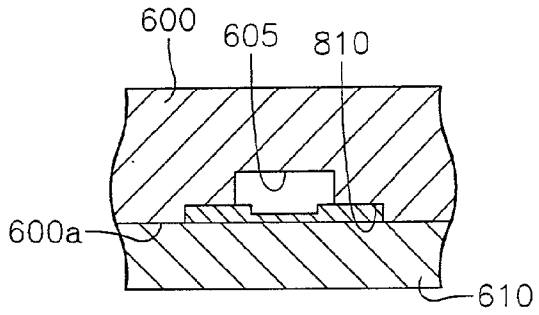


FIG. 9C

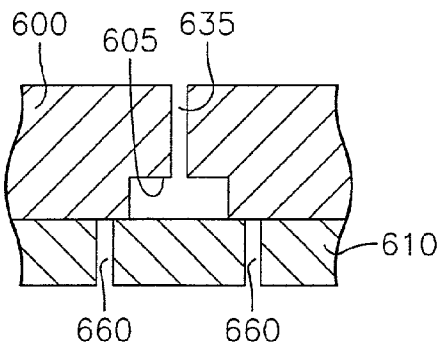


FIG. 8D

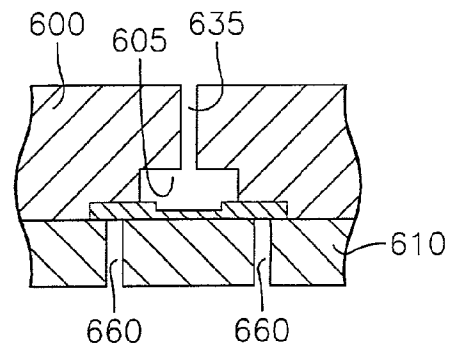


FIG. 9D

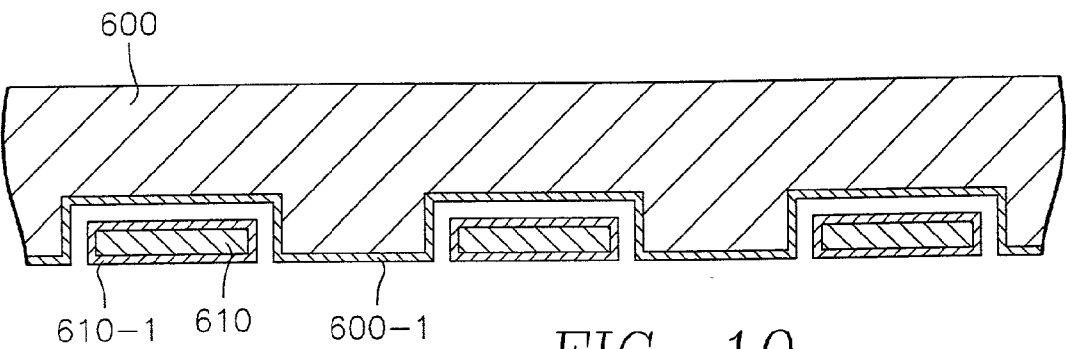


FIG. 10

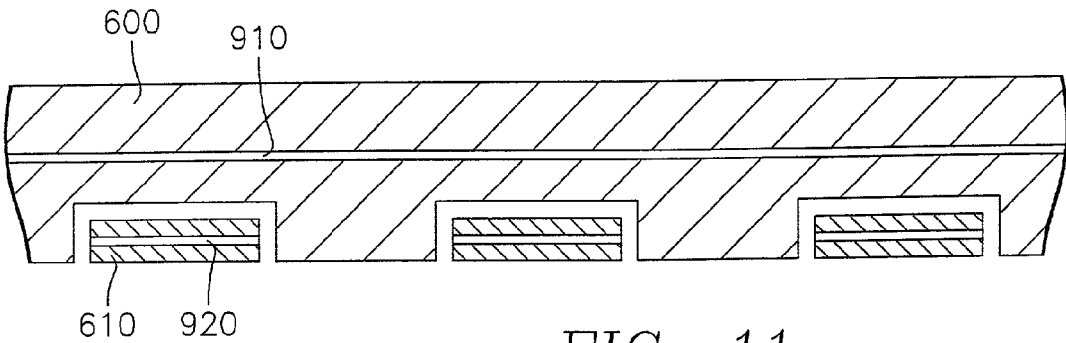


FIG. 11

## GAS DISTRIBUTION PLATE ELECTRODE FOR A PLASMA REACTOR

### BACKGROUND OF THE INVENTION

**[0001]** Various types of plasma reactors employed in the manufacture of semiconductor microelectronic circuits require a large RF electrode at the reactor chamber ceiling that overlies the semiconductor workpiece. Typically, the workpiece is a semiconductor wafer supported on a conductive pedestal. RF power is applied to the support pedestal, and the ceiling or overhead electrode is a counter electrode. In some reactors, the RF power applied to the support pedestal is the plasma source power (determining plasma ion density) and is also the plasma bias power (determining ion energy at the wafer surface). In other reactors, an RF power applicator other than the wafer pedestal furnishes the plasma source power, while the RF power applied to the wafer pedestal serves only as plasma RF bias power. For example, the plasma source power may be applied by an inductive antenna or may be applied by the ceiling electrode. Thus, the ceiling electrode may either be a grounded counter electrode for the RF power applied to the wafer support pedestal or it may be connected to an independent RF power generator and function as an independent RF power applicator. In either case, the most uniform distribution of process gas is obtained by introducing the process gas through the ceiling. This requires that the ceiling electrode be a gas distribution plate.

**[0002]** There is a continuing need to improve the uniformity of process gas distribution across the wafer surface in a plasma reactor, particularly in a plasma reactor used for semiconductor etch processes as well as other semiconductor processes. This need arises from the ever-decreasing device geometries of microelectronic circuits and minimum feature sizes, some approaching 0.15 microns. Such small device geometries are dictated in most cases by the desire for higher microprocessor clock speeds, and require corresponding improvements in etch rates, etch uniformity across the wafer surface and damage-free etching. Previously, with devices having relatively large feature sizes, a single gas inlet in the plasma reactor overhead ceiling electrode/gas distribution plate provided adequate process gas distribution uniformity. A single inlet would necessarily be of a large size in order to meet the requisite gas flow requirements.

**[0003]** One problem with such a large inlet is that it is more susceptible to plasma entering the inlet and causing arcing or plasma light-up within the inlet. Such arcing damages the plate and/or enlarges the inlet and consumes power. Sputtering of the plate material around the inlet can also contaminate the plasma with by-products of the sputtering. With a large hole, the maximum electric field occurs near the center of the hole, and this is the likeliest location for plasma light-up or arcing to begin. One solution proposed for reactors having a single gas inlet was to juxtapose a disk or puck in the center of the hole to keep gases away from the intense electric field at the hole center (U.S. Pat. No. 6,885,358 by Dan Maydan). However, with current device geometries incorporating very small feature sizes, much better process gas distribution uniformity across the wafer surface is required. As a result, a single gas distribution inlet or orifice in the ceiling gas distribution plate is inadequate to provide the requisite gas distribution uniformity. Thus, an overhead gas distribution plate is currently made by drilling

thousands of fine holes or orifices through the plate. The spatial distribution of such a large number of orifices improves gas distribution uniformity across the wafer surface. The smaller size makes each hole less susceptible to plasma entering the hole.

**[0004]** Unfortunately, it has not been practical to place or hold an individual puck in the center of each one of the thousands of holes to ward the gas away from the high intensity electric fields near the hole centers. Thus, in order to reduce plasma arcing, the gas inlet holes must be of minimal diameter and within a small dimensional hole-to-hole tolerance to ensure uniform gas distribution. Drilling such a large number of holes is costly. This is because the holes must have such a high aspect ratio, must be drilled through very hard material (such as silicon carbide) and sharp hole edges must be avoided. Moreover, the very need for such accurately sized holes means that performance is easily degraded as hole sizes are enlarged by plasma sputtering of the hole edges. Depending upon plasma ion density distribution across the ceiling surface, some holes will be widened at a greater rate than other holes, so that a gas distribution plate initially having highly uniform gas distribution across the wafer surface eventually fails to provide the requisite uniformity.

**[0005]** Another problem is that the need for greater etch rate has dictated a smaller wafer-to-ceiling gap in order to obtain denser plasma. The small gas orifices produce very high velocity gas streams. The high velocity gas streams thus produced can be so narrowly collimated within the narrow wafer-to-ceiling gap that the hole-to-hole spacing in the gas distribution plate produces corresponding peaks and valleys in gas density at the wafer surface and corresponding non-uniformities in etch rate across the wafer surface.

**[0006]** As a result, there is a need for an overhead gas distribution plate that functions as an electrode or counter electrode, and that is not susceptible to plasma arcing in the gas injection passages, that does not have high gas injection velocities and in which the gas distribution uniformity and velocity are not affected by enlargement of the gas injection passages.

### SUMMARY OF THE DISCLOSURE

**[0007]** The invention is embodied in a plasma reactor for processing a semiconductor wafer, the reactor having a gas distribution plate including a front plate in the chamber and a back plate on an external side of the front plate, the gas distribution plate comprising a gas manifold adjacent the back plate, the back and front plates bonded together and forming an assembly. The assembly includes an array of holes through the front plate and communicating with the chamber, at least one gas flow-controlling orifice through the back plate and communicating between the manifold and at least one of the holes, the orifice having a diameter that determines gas flow rate to the at least one hole. In addition, an array of pucks is at least generally congruent with the array of holes and disposed within respective ones of the holes to define annular gas passages for gas flow through the front plate into the chamber, each of the annular gas passages being non-aligned with the orifice.

### BRIEF DESCRIPTION OF THE DRAWINGS

**[0008]** **FIG. 1** is a simplified cut-away cross-sectional side view of a plasma reactor embodying the present invention.



[0009] FIG. 2A is a partially exploded cross-sectional side view of a gas distribution plate of the plasma reactor of FIG. 1 in accordance with a first embodiment.

[0010] FIG. 2B is a side view of an assembled gas distribution plate of the plasma reactor corresponding to FIG. 2A.

[0011] FIG. 3A is a plan view of one implementation of the front plate of the gas distribution plate of FIG. 2B.

[0012] FIG. 3B is a plan view of the front plate of FIG. 3A bonded to the back plate in accordance with this implementation.

[0013] FIG. 4 is a cross-sectional side view of the assembly of FIG. 3B corresponding to lines 4-4 of FIG. 3B.

[0014] FIG. 5 is a cross-sectional side view of a gas distribution plate of the plasma reactor of FIG. 1 in accordance with a second embodiment.

[0015] FIG. 6 is a cut-away partially exploded perspective view of a gas distribution plate of the plasma reactor of FIG. 1 in accordance with a third embodiment.

[0016] FIG. 7 is a cross-sectional view corresponding to lines 7-7 of FIG. 6.

[0017] FIGS. 8A, 8B, 8C and 8D are sequential cut-away partial side views of one portion of a gas distribution plate of FIG. 6, illustrating a first process for fabricating the gas distribution plate of FIG. 6.

[0018] FIGS. 9A, 9B, 9C and 9D are sequential cut-away partial side views of one portion of a gas distribution plate of FIG. 6, illustrating a second process for fabricating the gas distribution plate of FIG. 6.

[0019] FIG. 10 is a cross-sectional side view of a gas distribution plate of the plasma reactor of FIG. 1 in accordance with a third embodiment.

[0020] FIG. 11 is a cross-sectional side view of an alternate gas distribution plate as shown in FIG. 10.

#### DETAILED DESCRIPTION

[0021] Referring to FIG. 1, a plasma reactor includes a vacuum chamber 100 bounded by a reactor chamber cylindrical side wall 105, a ceiling 110 and floor 115. A vacuum pump 120 maintains a vacuum within the chamber at a desired chamber pressure. A wafer support pedestal 125 for supporting a semiconductor wafer or workpiece 130 is disposed at the bottom of the chamber 100 so that the wafer 130 faces the ceiling 110. The wafer support pedestal 125 has conductive elements so that the pedestal 125 can serve as an electrode or RF power applicator. For this purpose, an RF generator 135 is connected to the pedestal 125 through an RF impedance match circuit 140. The ceiling 110 is conductive in the illustrated embodiment and is connected to the RF return terminal of the RF generator 135 so that the ceiling 110 serves as a counter electrode for the wafer pedestal 125. In some types of reactors, another RF generator 145 may be connected to the ceiling 110 through an RF impedance match circuit 150, so that the ceiling 110 also serves as another RF power applicator. In this case, the frequencies of the two RF generators 135, 145 are very different so that the two RF generators 135, 145 function independently.

[0022] Process gas is introduced so as to provide maximum gas distribution uniformity across the top surface of the wafer 130 by injecting it through many uniformly spaced gas injection inlets 160 in the ceiling 110. The ceiling 110 is thus a gas distribution plate. A gas source or supply 165 is coupled to a gas manifold 170 in the ceiling/gas distribution plate 110, and the gas manifold 170 feeds each of the inlets 160. As shown in FIGS. 2A and 2B, the inlets 160 of the gas distribution plate 110 are formed by two parallel planar plates, namely a back plate 205 and a front plate 210 which are manufactured separately (FIG. 2A) and then bonded together (FIG. 2B). The back plate 205 is on top and the front plate 210 is on the bottom and faces the plasma in the interior of the chamber 100. The back plate 205 consists of an array of relatively large cylindrical openings 215 in its bottom surface while the front plate 210 consists of an array of cylindrical pucks 220 matching the array of openings 215. As shown in FIG. 2B, the pucks 220 of the front plate 210 fit within the openings 215 of the back plate 205, the clearance between each opening 215 and matching puck 220 forming an annular gap therebetween, the annular gap being the gas inlet 160. Gas feed orifices 230 in the back plate 205 are sized to provide the precise gas flow desired extend vertically from the gas manifold 170 overlying the back plate 205 to the annular gas inlets 160. Since the gas distribution plate 110 consists of an array of hundreds or thousands of annular inlets 160 to achieve spatially uniform gas distribution across the entire wafer surface, the inlets 160 would in most cases allow too much gas flow. Therefore, the finely-sized orifices 230 provide the requisite flow control.

[0023] Significantly, each orifice 230 faces a horizontal gap 235 between the respective puck 220 and the back plate 205, so that the gas is forced to make an abrupt turn to enter the gap 235 and another abrupt turn to enter the annular inlet 160. It is difficult if not impossible for plasma in the chamber travelling upward in the annular inlets 160 to make both of these turns without being extinguished by collisions with the gas distribution plate surfaces within the annular inlet 160 and the horizontal gap 235. A result is that the precisely sized orifices 230 are protected from plasma sputtering. This leaves only the annular inlets 160 subject to distortion in size from plasma sputtering or attack. However, the area of each annular inlet 160 is so large that plasma sputtering introduces only a small fractional difference in area from inlet to inlet, so that gas distribution uniformity across the wafer surface is virtually immune to such changes. Moreover, in the embodiment of FIGS. 2A and 2B, gas flow uniformity is determined by the uniformity of the orifices 230 only, so that changes in the sizes of the various annular inlets 160 have virtually no effect on gas flow uniformity. Thus, performance of the gas distribution plate 110 is virtually immune to changes induced by plasma sputtering or attack, a significant advantage.

[0024] In one embodiment, the back plate 205 and front plate 210 are formed of silicon carbide and are bonded together using existing techniques in silicon carbide manufacturing. One advantage of using silicon carbide as the material of the gas distribution plate 110 is that such material is practically impervious to attack by certain process gases and plasma species, such as halogen-containing process gases and plasma species. Also, silicon carbide is relatively compatible with silicon semiconductor wafer processing, so

that contamination from plasma sputtering of such material is not as harmful as are other materials such as aluminum.

[0025] Another advantage of the annular-shaped gas inlets 160 is that each puck 220 keeps the plasma ions and gases away from the center of each opening 215 where electric fields are maximum. This feature helps prevent arcing or plasma light-up. The two-plate structure 205, 210 of the gas distribution plate 110 enables cost-effective manufacture of hundreds or thousands of holes 215 and pucks 220 centered in each of the holes. The invention thus provides an economical gas distribution plate with sufficient uniformity of gas distribution to process extremely fine device features (e.g., 0.15 microns) on a very large wafer (10 inch to 20 inch diameter) with minimal plasma arcing while being impervious to long-term wear from plasma sputtering.

[0026] Another advantage is that the relatively large annular openings 160 provide a much lower gas injection velocity. Although each finely sized orifice 230 produces a very high velocity gas stream into the respective horizontal gap 235, passage through the horizontal gap 235 and through the large annular inlet 160 dissipates its velocity. As a result, the gas flow from the bottom of the front plate 210 is much more uniform and free from high velocity narrow gas streams and plasma plumes. Therefore, a small wafer-to-ceiling gap does not lead to spatial non-uniformities in the gas distribution at the wafer surface using the gas distribution plate 110, a significant advantage.

[0027] Many of the advantages enumerated above are pertinent to problems encountered in high power plasma reactors capable of high plasma ion densities. One of these problems is that high plasma ion density over the wafer surface is achieved in some reactors by a small wafer-to-ceiling gap to better confine the plasma. As noted above, the gas distribution plate 110 provides uniform gas distribution within such a small gap because of the large size of the annular inlets 160. Another one of these problems is that high plasma ion density is achieved in some reactors by applying plasma source power to the ceiling or overhead gas distribution plate, which leads to arcing in the gas inlets. As noted above, the gas distribution plate 110 includes the pucks 220 that confine the gas closer to the periphery of each hole 215 where electric fields are minimum so as to suppress or prevent arcing. Thus, the gas distribution plate 110 is inherently suitable for use in high density plasma reactors.

[0028] FIGS. 3A, 3B and 4 illustrate one implementation of the embodiment of FIGS. 2A and 2B. FIG. 3A shows that the front plate 210 having the array of pucks 220 consists of a web of longitudinal arms 310 and lateral arms 315 formed with the pucks 220 and holding them in the fixed array. Referring to FIGS. 3B and 4, the back plate 205 has longitudinal channels 320 and lateral channels 325 that receive the longitudinal and lateral arms 310, 315 when the plates 205, 210 are joined together. The pucks 220 are centered in the respective holes 215 and spaced apart from the back plate 205 by the horizontal gaps 235 and the annular inlets 160 and therefore do not contact the back plate 205. Contact between the back plate 205 and the front plate 210 is along the longitudinal and lateral arms 310, 315 that fit snugly within the corresponding longitudinal and lateral channels 320, 325. It is along these contacting surfaces that the two plates 205, 210 are bonded together. As noted previously above, if the two plates are silicon carbide

material, then the bonding is carried out using standard silicon carbide bonding techniques.

[0029] FIG. 5 illustrates an embodiment in which a single orifice 235a feeds a group of neighboring annular gas inlets 160a, 160b, 160c. The single orifice 235a feed the middle annular gas inlet 160b directly via the horizontal gap 235b, and feeds the adjacent annular inlets 160a, 160c through internal channels 505, 510 connecting the adjacent annular inlets 160a, 160c with the middle annular inlet 160b. One advantage of this embodiment is that the number of finely sized orifices 235 that must be drilled in the back plate 205 is greatly reduced.

[0030] FIG. 6 illustrates an embodiment in which a back plate 600 has parallel lateral slots 605 and a front plate 610 has an array of holes 615 and pucks 620. The circular holes 615 and the cylindrical pucks 620 are concentrically arranged so that they define corresponding annular gas ports 616. The slots 605 are aligned with respective rows of the holes 615 and pucks 620. The width of each slot 605 is less than the diameter of each hole 615 (e.g., less than half). The plates 600, 610 are joined together so that each slot 610 is centered with a respective row of the array of holes 615. Referring to the cross-sectional view of FIG. 7, the resulting gas passage aligned with each hole 615 consists of a pair of arcuate slots 630a, 630b which appear in FIG. 7 in solid line. Process gas is fed into each slot 605 by a single fine orifice 635 through the back plate 600. The diameter of the orifice 635 is selected to provide the requisite gas flow rate.

[0031] The embodiment of FIGS. 6 and 7 is simpler to form because there is no horizontal gap (e.g., the horizontal gap 235 of FIG. 2) between the puck 620 and the back plate 600. Instead, the bond between the plates 600, 610 is formed along the entirety of their adjoining surfaces. The pucks 620 are similarly bonded across the entirety of their top surfaces to the bottom surface of the plate 600. The only areas of the top surfaces of the pucks 620 not thus bonded are the areas facing the narrow slots 605.

[0032] In the foregoing embodiments, the pucks 620 function as flow diversion elements for transforming gas flow between the front and back plates 610, 600 from stream patterns in the back plate 600 to annular flow patterns in the front plate 610. The stream patterns correspond to a first radius (i.e., the radius of the top orifices 635) and the annular patterns correspond to a second radius (i.e., the radius of each annular opening 660) which is larger than the first radius. The flow diversion elements 620 induce a rapid change of gas flow (a) from a vertical flow of the stream pattern in each orifice 635 (b) to a horizontal flow from the first radius (of each orifice 635) to the second radius (of the corresponding annular opening 660) and (c) to a vertical flow in each corresponding annular opening 660.

[0033] FIGS. 8A-8D illustrate one method for fabricating the gas distribution plate of FIGS. 6 and 7 as a monolithic silicon carbide piece. In FIG. 8A, the back plate 600 is formed of sintered silicon carbide and the slots 605 are milled in the plate 600. In FIG. 8B, graphite inserts 805 are placed in the slots 605. In FIG. 8C, the front plate 610 is formed by chemical vapor deposition of silicon carbide on the bottom surface 600a of the back plate 600. Then, the graphite inserts are all removed by heating the entire assembly until the graphite material burns away, leaving the slots 605 empty, as shown in FIG. 8D. In FIG. 8D, an array of

annular openings **660** are milled completely through the entire thickness of the front plate **610**, corresponding to the holes **615** and pucks **620** illustrated in FIG. 6. FIG. 8D also depicts the orifice **635**, which may be milled during one of the foregoing steps.

[0034] FIGS. 9A-9D illustrate another method for fabricating the gas distribution plate of FIGS. 6 and 7 as a monolithic silicon carbide piece. In FIG. 9A, the back plate **600** is formed of sintered silicon carbide and the slots **605** are milled in the plate **600**. In addition, a wide shallow channel **810** is formed in the back plate **600** centered along and parallel to each slot **605**. In FIG. 8B, silicon carbide inserts **815** are placed in the wide shallow slots **810** in FIG. 8C, the front plate **610** is formed by chemical vapor deposition of silicon carbide on the bottom surface **600a** of the back plate **600**. In FIG. 8D, an array of annular openings **660** are milled completely through the combined thicknesses of the front plate **610** and the silicon carbide inserts **815**, corresponding to the holes **615** and pucks **620** illustrated in FIG. 6.

[0035] FIG. 10 illustrates yet another embodiment in which the back plate **600** and the front plate **610** are both formed of anodized aluminum. The anodization produces an alumina thin film **600-1** on the back plate **600** and an alumina thin film **610-1** on the front plate **610**. The anodization layer protects the aluminum plates from the plasma.

[0036] While the invention has been described with reference to embodiments in which the ceiling gas distribution plate must function as an electrode (and therefore comprise conductive material), the gas distribution plate of the invention is also well suited to applications in which the gas distribution plate does not function as an electrode.

[0037] In those embodiments in which the ceiling gas distribution plate functions as an overhead electrode, it may consist of silicon carbide, as described above. If it is desired that the gas distribution plate have a resistivity less than that of silicon carbide (0.005-1.0 Ohm-cm), then each of the silicon carbide plates **600**, **610** may be fabricated in such a manner as to have a thin highly conductive graphite layers **910**, **920** running through the center of the plates and co-planar with the respective plate, as illustrated in FIG. 11. This is accomplished by forming each plate **600**, **610** as a graphite plate. Each graphite plate is machined to form the structural features described above with reference to FIGS. 6 and 7. Then, each graphite plate **600**, **610** is siliconized using conventional techniques. However, the siliconization process is carried out only partially so as to siliconize the graphite plates to a limited depth beyond the external surface of the graphite. This leaves an interior portion of the graphite un-siliconized, corresponding to the graphite layers **910**, **920** enclosed within the silicon carbide plates **600**, **610**. The graphite layers **910**, **920** have a resistivity about one order of magnitude less than that of silicon carbide. Since the graphite layers **910**, **920** are completely enclosed in silicon carbide, they are protected from the plasma.

[0038] While the gas distribution plate of FIGS. 2A and 2B has been described as being formed of silicon carbide, it may, instead, be formed of silicin.

[0039] While the invention has been described in detail with reference to preferred embodiments, it is understood that variations and modifications thereof may be made without departing from the true spirit and scope of the invention.

What is claimed is:

1. A plasma reactor for processing a semiconductor wafer, said reactor comprising:

a vacuum chamber side wall;

a wafer support pedestal for supporting said semiconductor wafer in said chamber;

an RF power source coupled to said wafer support pedestal;

a process gas source;

a gas distribution plate at a ceiling location of said chamber, said gas distribution plate comprising:

a front plate in said chamber and a back plate on an external side of said front plate, said gas distribution plate comprising a gas manifold adjacent said back plate, said back and front plates bonded together and forming an assembly comprising:

(a) an array of holes through said front plate and communicating with said chamber,

(b) at least one gas flow-controlling orifice through said back plate and communicating between said manifold and at least one of said holes, said orifice having a diameter that determines gas flow rate to the at least one hole;

(c) an array of pucks at least generally congruent with said array of holes and disposed within respective ones of said holes to define annular gas passages for gas flow through said front plate into said chamber, each of said annular gas passages being non-aligned with said orifice.

2. The reactor of claim 1 wherein said assembly further comprises an array of gas flow-controlling orifices through said back plate communicating between said manifold and corresponding ones of said array of holes.

3. The reactor of claim 2 wherein each of said orifices faces a corresponding one of said pucks, said assembly further comprising a planar gap between each of said pucks a facing surface of said back plate, each planar gap communicating between the corresponding orifice and the corresponding annular gas passage.

4. The reactor of claim 1 wherein said assembly further comprises:

one gas flow-controlling orifice through said back plate for each predetermined group of neighboring holes, said orifice generally facing a center one of the holes of the corresponding group of neighboring holes;

internal gas passages connecting the center one of the holes with the other holes in said group of neighboring holes.

5. The reactor of claim 3 wherein said back plate comprises said array of holes and said front plate comprises said array of pucks.

6. The reactor of claim 5 wherein said front and back plates comprises silicon carbide.

7. The reactor of claim 6 wherein at least one of said plates further comprises an enclosed planar layer of graphite extending parallel with a plane of said plate.

8. The reactor of claim 5 wherein said front and back plates comprises anodized aluminum.

9. The reactor of claim 5 wherein said gas distribution plate comprises a ceiling electrode of said reactor, said reactor further comprising a second RF power source coupled to said gas distribution plate.

10. The reactor of claim 5 wherein said gas distribution plate comprises a counter electrode to said wafer support pedestal, said RF power source being connected across said wafer support pedestal and said gas distribution plate.

11. The reactor of claim 1 wherein said array of holes is arranged in parallel rows of said holes, said assembly further comprising:

plural elongate slots in said back plate overlying and opening into the holes of the corresponding rows of holes, each of said slots communicating between said orifice and the holes in the corresponding row of holes.

12. The reactor of claim 11 wherein said assembly further comprises plural gas flow-controlling orifices corresponding to the plural rows of said holes, each of said slots communicating between a corresponding one of said orifices and the corresponding row of holes.

13. The reactor of claim 11 wherein said orifice is not aligned with the annular gaps formed between said pucks and said holes.

14. The reactor of claim 11 wherein each of said elongate slots has a width less than the diameter of each of said holes, and wherein each of said pucks contacts a facing surface of said front plate.

15. The reactor of claim 8 wherein each of said annular gas passages is divided into a pair of partial arcuate annular sections.

16. The reactor of claim 15 wherein said partial annular passages correspond to a coincidence between the annular gap formed by each puck within the corresponding hole and the corresponding slot.

17. The reactor of claim 11 wherein said holes and pucks are formed in said front plate and said slots and orifice are formed in said back plate.

18. The reactor of claim 17 wherein said front and back plates comprise silicon carbide.

19. The reactor of claim 18 wherein at least one of said plates further comprises an enclosed planar layer of graphite extending parallel with a plane of said plate.

20. The reactor of claim 17 wherein said front and back plates comprises anodized aluminum.

21. The reactor of claim 17 wherein said gas distribution plate comprises a ceiling electrode of said reactor, said reactor further comprising a second RF power source coupled to said gas distribution plate.

22. The reactor of claim 17 wherein said gas distribution plate comprises a counter electrode to said wafer support pedestal, said RF power source being connected across said wafer support pedestal and said gas distribution plate.

23. For installation at a ceiling location of a plasma reactor for processing a semiconductor wafer and having a vacuum chamber side wall, a wafer support pedestal for supporting said semiconductor wafer in said chamber, an RF power source coupled to said wafer support pedestal and a process gas source:

a gas distribution plate comprising:

a front plate in said chamber and a back plate on an external side of said front plate, said gas distribution plate comprising a gas manifold adjacent said back

plate, said back and front plates bonded together and forming an assembly comprising:

(a) an array of holes through said front plate and communicating with said chamber,

(b) at least one gas flow-controlling orifice through said back plate and communicating between said manifold and at least one of said holes, said orifice having a diameter that determines gas flow rate to the at least one hole;

(c) an array of pucks at least generally congruent with said array of holes and disposed within respective ones of said holes to define annular gas passages for gas flow through said front plate into said chamber, each of said annular gas passages being non-aligned with said orifice.

24. The reactor of claim 22 wherein said assembly further comprises an array of gas flow-controlling orifices through said back plate communicating between said manifold and corresponding ones of said array of holes.

25. The reactor of claim 24 wherein each of said orifices faces a corresponding one of said pucks, said assembly further comprising a planar gap between each of said pucks a facing surface of said back plate, each planar gap communicating between the corresponding orifice and the corresponding annular gas passage.

26. The reactor of claim 23 wherein said assembly further comprises:

one gas flow-controlling orifice through said back plate for each predetermined group of neighboring holes, said orifice generally facing a center one of the holes of the corresponding group of neighboring holes;

internal gas passages connecting the center one of the holes with the other holes in said group of neighboring holes.

27. The reactor of claim 25 wherein said back plate comprises said array of holes and said front plate comprises said array of pucks.

28. The reactor of claim 27 wherein said front and back plates comprises silicon carbide.

29. The reactor of claim 28 wherein at least one of said plates further comprises an enclosed planar layer of graphite extending parallel with a plane of said plate.

30. The reactor of claim 27 wherein said front and back plates comprises anodized aluminum.

31. The reactor of claim 23 wherein said array of holes is arranged in parallel rows of said holes, said assembly further comprising:

plural elongate slots in said back plate overlying and opening into the holes of the corresponding rows of holes, each of said slots communicating between said orifice and the holes in the corresponding row of holes.

32. The reactor of claim 31 wherein said assembly further comprises plural gas flow-controlling orifices corresponding to the plural rows of said holes, each of said slots communicating between a corresponding one of said orifices and the corresponding row of holes.

33. The reactor of claim 31 wherein said orifice is not aligned with the annular gaps formed between said pucks and said holes.

**34.** The reactor of claim 31 wherein each of said elongate slots has a width less than the diameter of each of said holes, and wherein each of said pucks contacts a facing surface of said front plate.

**35.** The reactor of claim 34 wherein each of said annular gas passages is divided into a pair of partial arcuate annular sections.

**36.** The reactor of claim 35 wherein said partial annular passages correspond to a coincidence between the annular gap formed by each puck within the corresponding hole and the corresponding slot.

**37.** The reactor of claim 31 wherein said holes and pucks are formed in said front plate and said slots and orifice are formed in said back plate.

**38.** The reactor of claim 37 wherein said front and back plates comprise silicon carbide.

**39.** The reactor of claim 38 wherein at least one of said plates further comprises an enclosed planar layer of graphite extending parallel with a plane of said plate.

**40.** The reactor of claim 31 wherein said front and back plates comprises anodized aluminum.

**41.** The reactor of claim 23 where the annular gas passages are circular.

**42.** The reactor of claim 23 wherein the annular gas passages are non-circular.

**43.** A method of fabricating a gas distribution plate for use in processing semiconductor wafers in a plasma reactor, the gas distribution plate comprising silicon carbide and having plural parallel slots communicating above with respective gas flow-controlling orifices and below with respective rows of annular gas injection passages, said method comprising:

forming parallel slots in one surface of a silicon carbide plate;

filling said slots with graphite inserts;

depositing a layer of silicon carbide on said one surface of said silicon carbide plate;

removing said graphite inserts by heating said plate;

drilling respective rows of annular openings through the deposited layer of silicon carbide communicating with respective ones of said slots.

**44.** A method of fabricating a gas distribution plate for use in processing semiconductor wafers in a plasma reactor, the gas distribution plate comprising silicon carbide and having plural parallel slots communicating above with respective gas flow-controlling orifices and below with respective rows of annular gas injection passages, said method comprising:

forming parallel slots in one surface of a silicon carbide plate;

covering said slots with silicon carbide inserts;

depositing a layer of silicon carbide on said one surface of said silicon carbide plate;

drilling respective rows of annular openings through the deposited layer of silicon carbide and through said silicon carbide inserts, said annular openings communicating with respective ones of said slots.

**45.** A plasma reactor for processing a semiconductor wafer, said reactor comprising:

a vacuum chamber side wall;

a wafer support pedestal for supporting said semiconductor wafer in said chamber;

an RF power source coupled to said wafer support pedestal;

a process gas source;

a gas distribution plate at a ceiling location of said chamber, said gas distribution plate comprising:

a front plate in said chamber and a back plate on an external side of said front plate, said gas distribution plate comprising a gas manifold adjacent said back plate, said back and front plates bonded together and forming an assembly comprising:

(a) an array of holes through said front plate and communicating with said chamber,

(b) at least one gas flow-controlling orifice through said back plate and communicating between said manifold and at least one of said holes, said orifice having a diameter that determines gas flow rate to the at least one hole;

(c) flow diversion elements for transforming gas flow between said front back plates from stream patterns in said back plate to annular flow patterns in said front plate.

**46.** The plasma reactor of claim 45 wherein:

said stream patterns correspond to a first radius and said annular patterns correspond to a second radius larger than said first radius;

said flow diversion elements induce a rapid change of gas flow (a) from a vertical flow in each stream pattern (b) to a horizontal flow from said first radius to said second radius and (c) to a vertical flow each corresponding annular pattern.

\* \* \* \* \*