

REACTOR FOR TREATING GASEOUS POLLUTANTS AND HEAD ASSEMBLY THEREOF

FIELD OF THE INVENTION

The present invention relates to a reactor for treating gaseous pollutants
5 and a head assembly thereof, and more particularly to a reactor for treating
an effluent from a semiconductor process and a head assembly thereof.

BACKGROUND OF THE INVENTION

Effluent generated in semiconductor processes contains various
chemical substances that are harmful to human health or the environment.
10 Common effluent treatment systems include combustion-type, plasma-type,
wet scrubbing, and catalytic systems.

For pollutants such as silane (SiH_4), arsine (AsH_3), and phosphine (PH_3)
generated in chemical vapor deposition (CVD) processes, combustion-type
effluent treatment systems are commonly employed. Conventional
15 commercial products include, for example, the ESCAPE systems from
DAS Environmental Expert GmbH and the Spectra series from Edwards.
In addition, for perfluorinated compounds (PFCs) (e.g., CF_4) and other
greenhouse gases such as SF_6 , NF_3 , and N_2O , plasma-type effluent
treatment systems are typically used. Conventional commercial products
20 include, for example, the Proteus series from Edwards.

Representative disclosures may also be found in U.S. Pat. Nos.
US20220088529A1, US11430638B2, US20180243687A1, and
US20140079617A1. In typical plasma-type effluent treatment systems, a
top-inlet configuration is commonly adopted, and plasma reactions are
25 performed at an upper portion of the reactor. As a result, a top cover or an

upper outer wall of the reactor exhibits elevated temperatures, which may pose safety risks during operation.

SUMMARY OF THE INVENTION

The present disclosure provides a head assembly configured to be
5 installed on a plasma reactor for treating gaseous pollutants. The head assembly comprises a cover assembly, one or more plasma modules, and one or more guiding conduit assemblies. The cover assembly is disposed above a plasma reaction region. The cover assembly comprises a top plate and a bottom plate, and a region for accommodating a cooling fluid is
10 provided between the top plate and the bottom plate. The bottom plate comprises one or more openings. The plasma modules are connected to the plasma reaction region through the openings. Each of the plasma modules comprises a microwave source configured to generate a microwave oscillation, a waveguide assembly coupled to the microwave source and
15 configured to transmit the microwave oscillation, and a resonant cavity coupled to the waveguide assembly and configured to guide the microwave oscillation substantially along a waveguide direction. The resonant cavity comprises a first chamber proximate to the waveguide assembly and a second chamber distal from the waveguide assembly. The second chamber
20 receives the microwave oscillation passing through the first chamber, and the microwave oscillation reacts with a reaction gas to form a plasma field in the plasma reaction region, wherein a formation orientation of the plasma field is along a first direction. The guiding conduit assemblies are configured to guide an effluent stream from a semiconductor process to the
25 plasma reaction region. A flow direction of the effluent stream is along a

second direction, the first direction intersects the second direction at an angle, and the one or more guiding conduit assemblies are configured to generate a cyclone in the plasma field.

The present disclosure further provides a reactor for treating gaseous pollutants, comprising one or more inlet modules, one or more plasma modules, a reaction module, and a cooling module. The inlet modules each comprise one or more guiding conduit assemblies configured to guide an effluent stream from a semiconductor process. The plasma modules are in communication with the inlet modules. Each of the plasma modules comprises a microwave source configured to generate a microwave oscillation, a waveguide assembly coupled to the microwave source and configured to transmit the microwave oscillation, and a resonant cavity coupled to the waveguide assembly and configured to guide the microwave oscillation substantially along a waveguide direction. The reaction module is coupled below the inlet modules and the plasma modules. The reaction module comprises a plasma reaction chamber, a bottom chamber located below the plasma reaction chamber, and a cover assembly disposed at an upper opening of the plasma reaction chamber. The plasma modules extend substantially vertically through the cover assembly such that the guiding conduit assemblies guide the effluent stream into the plasma reaction chamber. The cover assembly comprises a top plate and a bottom plate, and a region is defined between the top plate and the bottom plate. The cooling module comprises a cooling fluid source and one or more cooling conduits connected to the cooling fluid source, wherein the cooling conduits are configured to supply cooling water to the region.

The present disclosure further provides a reactor for treating gaseous pollutants, comprising a reactor, one or more guiding conduit assemblies, and one or more plasma modules. The reactor comprises a reactor body, an internal region defined by the reactor body, and a partition separating the
5 internal region from an exterior. The partition comprises an outer cover plate and a space disposed within the reactor body and adjacent to the outer cover plate. The guiding conduit assemblies are configured to guide an effluent stream from a semiconductor process into the internal region of the reactor. The plasma modules are disposed above the reactor. Each of the plasma
10 modules comprises a microwave source configured to generate a microwave oscillation, a waveguide assembly coupled to the microwave source and configured to transmit the microwave oscillation, and a resonant cavity coupled to the waveguide assembly and configured to guide the microwave oscillation substantially along a waveguide direction. The
15 resonant cavity comprises a first chamber proximate to the waveguide assembly and a second chamber distal from the waveguide assembly. The second chamber receives the microwave oscillation passing through the first chamber, and the microwave oscillation reacts with a reaction gas to form a plasma field in the internal region. The plasma field decomposes the
20 effluent stream within the internal region, and the space is provided with a medium for reducing heat transfer such that a temperature of the partition is lower than that of the internal region.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a schematic perspective view of an assembled apparatus according
25 to an embodiment of the present invention.

FIG. 2 is a schematic perspective view of an assembled apparatus according to an embodiment of the present invention.

FIG. 3 is a schematic perspective cross-sectional view of FIG. 1 taken along a YZ plane.

5 FIG. 4 is an enlarged partial view of FIG. 3.

FIG. 5 is an enlarged partial view of a plasma module according to an embodiment of the present invention.

FIGS. 6A to 6B are cross-sectional views of FIG. 1 taken along line A-A.

FIG. 7 is a cross-sectional view of FIG. 1 taken along a YZ plane.

10 FIG. 8 is an enlarged partial view of FIG. 7.

FIGS. 9A to 9B are exploded views of a cover assembly according to an embodiment of the present invention.

FIG. 10 is a schematic perspective cross-sectional view of FIG. 1 taken along an XZ plane.

15 **DETAILED DESCRIPTION**

The following embodiments are applied to the treatment of an effluent stream from a semiconductor process, such as waste gas. Although the term “water” is used in multiple instances herein, this terminology is solely for convenience of description, and the present invention is not limited thereto,
20 other alternative liquids may be used.

As used herein, the terminology employed in the description of various embodiments is for the purpose of describing particular examples and is not intended to be limiting. Unless the context clearly indicates otherwise, or unless the number of elements is expressly limited, the singular forms “a,”
25 “an,” and “the” may also include plural forms. In addition, the terms

“comprising” and “including” are intended to be inclusive, indicating that additional elements beyond those listed may be present. When an element is described as being “connected” or “coupled” to another element, the element may be directly connected or coupled to the other element, or may
5 be connected or coupled to the other element through an intermediate element. When a layer, region, or substrate is described as being “on” another element, it may be directly on the other element or may have an intermediate element therebetween. In contrast, when an element is described as being “directly on” another element, no such intermediate
10 element is present. In addition, the order of description of the embodiments should not be construed as implying that operations or steps must follow the literal order described, and alternative embodiments may perform steps, operations, or methods in an order different from that described herein.

An aspect of the present invention discloses a plasma-type waste gas
15 treatment apparatus. In one example, the waste gas treatment apparatus is a plasma and wet scrubbing type waste gas treatment apparatus. Referring to FIGS. 1 to 3, FIGS. 1 and 2 are schematic perspective views of an assembled apparatus according to an embodiment of the present invention. In the present embodiment, the waste gas treatment apparatus includes a
20 plasma reaction and wet scrubbing unit 10, a water tank unit 20, a secondary wet scrubbing unit 30, a filter unit, and a demisting unit. The waste gas treatment apparatus may be controlled by a control unit.

The plasma reaction and wet scrubbing unit 10 and the secondary wet scrubbing unit 30 are respectively disposed above the water tank unit 20.
25 The filter unit is coupled to the secondary wet scrubbing unit 30 and is

located above the secondary wet scrubbing unit 30. The demisting unit is coupled to the filter unit and is located above the filter unit. In other words, the secondary wet scrubbing unit 30, the filter unit, and the demisting unit are sequentially located downstream of the plasma reaction and wet scrubbing unit 10.

The plasma reaction and wet scrubbing unit 10 may be connected downstream of a semiconductor processing apparatus. The plasma reaction and wet scrubbing unit 10 includes one or more inlet modules 11, one or more plasma modules 12, a reaction module 13, a cooling module 14, and a spraying module 15. In some examples, the plasma reaction and wet scrubbing unit 10 may also be connected downstream of, but not limited to, solar cell processing equipment or display panel processing equipment, and receives an effluent stream from such equipment.

The inlet module 11 includes a plurality of guiding conduit assemblies 110. In this example, the number of the guiding conduit assemblies 110 is two, and the guiding conduit assemblies 110 receive an effluent stream from the semiconductor processing apparatus. Each guiding conduit assembly 110 includes an upstream guiding conduit 1101, a first branch conduit 1102, and a second branch conduit 1103. The first branch conduit 1102 and the second branch conduit 1103 respectively include vertical portions 1102a, 1103a and turning portions 1102b, 1103b. The upstream guiding conduit 1101 extends vertically along a Z-axis. The first branch conduit 1102 and the second branch conduit 1103 are connected downstream of the upstream guiding conduit 1101. The vertical portions 1102a, 1103a also extend vertically along the Z-axis. The turning portions 1102b, 1103b respectively

include first segments 1104a, 1104b and second segments 1105a, 1105b. The first segments 1104a, 1104b are curved to guide the effluent stream from the Z-axis direction to a Y-axis direction, and the second segments 1105a, 1105b are curved to guide the effluent stream from the Y-axis
5 direction to an X-axis direction, such that the effluent stream enters the plasma module 12 along a horizontal direction of the X-axis.

The plasma module 12 includes a microwave source 121, a waveguide assembly 122, a resonant cavity 123, an inlet chamber 124, a dielectric tube 125, a cooling assembly 126, and a moving member 127. In the present
10 embodiment, the microwave source 121 is a magnetron. The microwave source 121 may generate a microwave oscillation. The waveguide assembly 122 is disposed adjacent to and coupled to the microwave source 121 to transmit the microwave oscillation. The resonant cavity 123 is coupled to the waveguide assembly 122 and allows the microwave
15 oscillation to be transmitted substantially along a waveguide direction. The inlet chamber 124 is coupled below the resonant cavity 123 and communicates with the reaction module 13.

Referring to FIGS. 4 and 5, the resonant cavity 123 includes a first chamber 1231, a second chamber 1232, an inlet end 1233, a communication
20 end 1234, and a closed end 1235. The first chamber 1231 is disposed adjacent to the waveguide assembly 122, and the second chamber 1232 is disposed away from the waveguide assembly 122. The second chamber 1232 is configured to receive the microwave oscillation passing through the first chamber 1231, and the microwave oscillation reacts with one or more
25 reaction gases. In one embodiment of the present invention, the first

chamber 1231 extends along a reference axis L, and the microwave oscillation is transmitted within the resonant cavity 123 substantially parallel to the waveguide direction, wherein the waveguide direction is close to or substantially equal to the reference axis L. The first chamber

5 1231 has an inner wall surrounding the reference axis L and extending along the reference axis L. The inner wall includes a first region and a second region. The first region is inclined with respect to the reference axis L, and the second region is substantially parallel to the reference axis L. An area of the first region is greater than that of the second region, such that the first

10 chamber 1231 forms a tapered conical space from the inlet end 1233 to the communication end 1234.

As shown in FIG. 5, the dielectric tube 125 includes a first segment 1251, a second segment 1252, a third segment 1253, a top end 1254, and a bottom end 1255. The first segment 1251 and the third segment 1253

15 respectively protrude from the second chamber 1232, and the second segment 1252 is located within the second chamber 1232. The cooling assembly 126 is disposed at a side of the top end 1254 of the dielectric tube 125 and surrounds the first segment 1251 of the dielectric tube 125. The cooling assembly 126 includes a gas chamber 1261, a gas conduit 1262,

20 and a cooling conduit 1263. The gas chamber 1261 communicates with a hollow portion H of the dielectric tube 125. An inner wall of the gas chamber 1261 has at least one vent hole 1264, and the reaction gas enters the gas chamber 1261 through the vent hole 1264 and then enters the hollow portion H of the dielectric tube 125. In one embodiment, the reaction gas is

25 a non-fuel gas, such as an inert gas, for example nitrogen (N₂), argon (Ar),

or compressed dry air (CDA). The cooling conduit 1263 is configured to allow a cooling fluid to flow therethrough to control a temperature of the gas chamber 1261 and prevent component damage. The moving member 127 is connected to a probe assembly 1271 and is disposed on the cooling assembly 126. The moving member 127 controls vertical movement of the probe assembly 1271 relative to the second chamber 1232. In the present embodiment, the probe assembly 1271, the moving member 127, and the cooling assembly 126 may be collectively referred to as a plasma field generating source. However, this is merely an example, and other configurations may be adopted depending on practical applications. In the present embodiment, the moving member 127 may be a cylinder.

The microwave oscillation exhibits a peak intensity in the second chamber 1232 of the resonant cavity 123, and the peak intensity is located within the hollow portion H of the second segment 1252 of the dielectric tube 125. When the reaction gas fills the hollow portion H of the dielectric tube 125, the moving member 127 controls the probe assembly 1271 to move downward into the hollow portion H within the second segment 1252. When the maximum intensity of the microwave oscillation reaches a minimum threshold, a plasma field is formed downward in the hollow portion H, and a large number of positive ions, negative ions, or both positive and negative ions are released downward. The formation direction of the plasma field may be along a first direction (e.g., a Z-axis direction), and a flow direction of the effluent stream may be along a second direction (e.g., an X-axis direction). The first direction may intersect the second direction at an angle, for example, 90°.

Referring to FIGS. 6A and 6B, which are cross-sectional views of FIG. 1 taken along an A-A direction (with an XY plane as the cross section in the viewing direction of A-A), in this example, the inlet chamber 124 extends along a vertical direction (Z-axis direction), and the first branch conduit 1102 and the second branch conduit 1103 extend along a horizontal direction (X-axis direction) and enter the inlet chamber 124 from opposite sides thereof. The second segments 1105a, 1105b of the first branch conduit 1102 and the second branch conduit 1103 are respectively offset relative to an axial center of the inlet chamber 124, and the second segments 1105a, 1105b are parallel to each other in the XY plane but are offset from each other (i.e., not aligned). Accordingly, after the effluent stream enters the inlet chamber 124 through the second segments 1105a, 1105b, a cyclone is generated, thereby increasing collisions of gases and between the gas and the plasma, and improving decomposition efficiency.

In addition, the inlet chamber 124 further includes a deflector 1241. The deflector 1241 is disposed adjacent to side openings 1242, 1243 of the inlet chamber 124 that communicate with the second segments 1105a, 1105b. The deflector 1241 has a conical shape and includes an inclined conical surface 1241a. A height of the conical surface 1241a is lower than that of the side openings 1242, 1243, such that when the effluent stream enters the inlet chamber 124, the effluent stream is guided upward by the deflector 1241, thereby facilitating formation of the cyclone.

In one example, the dielectric tube 125 extends along the first direction into the inlet chamber 124. The guiding conduit assembly 110 includes a

first inlet 110a and a second inlet 110b, and the first inlet 110a and the second inlet 110b extend along the second direction into the inlet chamber 124. The first inlet 110a communicates with the side opening 1242, and the second inlet 110b communicates with the side opening 1243. The first inlet
5 110a and the second inlet 110b are disposed opposite each other on an annular wall 124a of the inlet chamber 124, and are offset relative to each other. The deflector 1241 partially blocks the first inlet 110a and the second inlet 110b to affect a flow of the effluent stream entering the inlet chamber 124.

10 Referring to FIGS. 7 and 8, the reaction module 13 is a plasma reactor and is coupled below the inlet module 11 and the plasma module 12. The reaction module 13 includes a reactor body 131 and a cover assembly 132. The reactor body 131 may be cylindrical or conical and defines a plasma reaction chamber 131a, an upper opening 131b located above the plasma
15 reaction chamber 131a, and a bottom chamber 131c located below the plasma reaction chamber 131a.

The cover assembly 132 is disposed at the upper opening 131b. Referring to FIGS. 9A and 9B, the cover assembly 132 includes a top plate 1321 and a bottom plate 1322, which are stacked. In this example, a bottom
20 surface 1321b of the top plate 1321 is planar, and the bottom plate 1322 has a recessed structure 1322b, such that a region 132a is provided between the top plate 1321 and the bottom plate 1322. The region 132a is a space extending along an XY plane and is configured to receive a cooling fluid. An annular wall 1323 is disposed between the top plate 1321 and the bottom

plate 1322, and the top plate 1321, the bottom plate 1322, and the annular wall 1323 define the region 132a. The top plate 1321 includes one or more openings 1321a, and the bottom plate 1322 includes one or more openings 1322a. The openings 1321a and 1322a correspond to each other in a vertical direction and communicate with the plasma reaction chamber 131a. In this embodiment, two openings 1321a and two openings 1322a are provided, respectively.

The inlet chamber 124 of the plasma module 12 communicates with the openings 1321a such that the plasma module 12 is disposed above the openings 1321a. The guiding conduit assembly 110 is inserted into the inlet chamber 124, such that gas outlets are exposed in the plasma reaction chamber 131a through the openings 1321a and 1322a. In this example, two plasma modules 12 are provided and can be seen in a top view, and each of the plasma modules 12 is disposed at opposite sides of the cover assembly 132 and aligned with the openings 1321a. The resonant cavity 123 and the inlet chamber 124 of the plasma module 12 are oriented toward the reaction module 13. The guiding conduit assembly 110 of the inlet module 11 communicates laterally with the inlet chamber 124, such that the effluent stream enters the inlet chamber 124 through the guiding conduit assembly 110 and flows into the plasma reaction chamber 131a. Accordingly, the microwave oscillation provided by the plasma module 12 reacts with a reaction gas to form a plasma field, such that the plasma reaction chamber 131a serves as a plasma reaction region in which the effluent stream is decomposed by plasma. The cover assembly 132 is substantially located

above the plasma reaction region.

The cooling module 14 (as shown in FIG. 10) includes a cooling fluid source and one or more cooling conduits 141 connected to the cooling fluid source. The cooling conduits 141 are transversely inserted into the annular wall 1323 between the bottom plate 1322 and the top plate 1321, and supply
5 a cooling fluid (such as cooling water) to the region 132a. The cooling water may circulate through a circulation conduit to form circulating cooling water.

By means of the cooling design of the cover assembly 132, a
10 temperature near the top plate 1321 is lower than a temperature of the plasma reaction chamber 131a in which plasma is generated, thereby reducing operational risks to personnel. The region 132a adjacent to the exterior contains flowing cooling water, which effectively removes heat. In one embodiment, when cooling water having a temperature between 16°C
15 and 20°C (for example, 18°C) is used, even when the temperature of the plasma reaction chamber 131a exceeds 500°C, or even exceeds 900°C, the temperature near the top plate 1321 can be maintained below 200°C, thereby significantly improving safety for operators and the operating environment. In contrast, in a plasma-type waste gas treatment apparatus
20 without the cooling module 14 and the cover assembly 132, when the plasma reaction chamber 131a is in operation, an external temperature exceeds 200°C, exposing operators to hazardous conditions.

In one example, the reactor body 131 defines an internal region (i.e., the plasma reaction chamber 131a) in the reaction module 13, and the cover

assembly 132 serves as a partition separating the internal region from the exterior. The cover assembly 132 (i.e., the partition) includes an outer cover plate and a space provided within the reactor body 131 and adjacent to the outer cover plate (i.e., the region 132a). The microwave oscillation reacts
5 with a reaction gas to generate plasma within the plasma reaction chamber 131a, such that the effluent stream is decomposed within the internal region. The space is provided with a medium (such as the cooling fluid) for reducing heat transfer, such that a temperature of the partition is significantly lower than that of the internal region.

10 A lateral annular gap 1312 is provided between the upper opening 131b of the reactor body 131 and the cover assembly 132. An outer casing of the reactor body 131 is provided with a water reservoir 134. The water reservoir 134 is connected to an annular flange, and the annular flange includes a plurality of conduits connected to a water source via a plurality of pipelines,
15 thereby supplying water to the water reservoir 134. A stream of water from the water reservoir 134 flows through the annular gap 1312 into the plasma reaction chamber 131a and flows downward along an inner wall 1311a thereof to form a water curtain, thereby washing the effluent stream entering the plasma reaction chamber 131a and cleaning dust, particles, or
20 contaminants adhering to the inner wall 1311a.

The reaction module 13 further includes a gas inlet unit 135 disposed above the plasma reaction chamber 131a and the water reservoir 134 to provide compressed dry gas.

The spraying module 15 includes a plurality of spray nozzles 151. In a

side view, the spray nozzles 151 are arranged obliquely and downward in the bottom chamber 131c. In a top view, the spray nozzles 151 are oriented non-radially and are offset in the same direction, thereby providing an improved spraying effect. The spray nozzles 151 dispense an effluent
5 treating agent. The effluent treating agent may be water or water mixed with corrosive agents, acidic agents, ionic or non-ionic surfactants, or coagulants. The spray nozzles 151 may deliver the effluent treating agent in the form of a liquid stream or a mist, and the effluent treating agent is capable of capturing harmful gases or particles in the effluent.

10 Referring to FIG. 10, the reactor body 131 communicates with the water tank unit 20 via the bottom chamber 131c. The water tank unit 20 includes a water-filled space 21, a partition member 22, a first upper opening 23a, and a second upper opening 23b. The partition member 22 is disposed in the water-filled space 21 and divides the water-filled space 21
15 into a first region 21a and a second region 21b, wherein the first region 21a and the second region 21b are in communication with each other. The water-filled space 21 stores circulating water, and a water level is lower than a top 24 of the water tank unit 20 and higher than the partition member 22, such that lateral flow passages are provided in the first region 21a and the
20 second region 21b to allow the effluent stream to flow laterally therethrough. The first upper opening 23a and the second upper opening 23b communicate with the first region 21a. The first upper opening 23a communicates with the plasma reaction and wet scrubbing unit 10, and the second upper opening 23b communicates with the secondary wet scrubbing

unit 30. In addition, the water tank unit 20 further includes a suction port 26 and a water inlet 27 (as shown in FIG. 2). The suction port 26 is coupled to a pump piping, and the water inlet 27 is configured to supply water, which may be fresh make-up water or recirculating water.

5 The secondary wet scrubbing unit 30 may be a packed bed scrubber. The secondary wet scrubbing unit 30 includes a lower opening 31, one or more chambers 32, one or more spray heads 33, and an upper opening 34. The lower opening 31 is connected to the second upper opening 23b, and the upper opening 34 is connected to the filter unit. The chambers 32 are
10 configured to hold a packing material having a high surface-to-volume ratio. The packing material may be made of polyvinyl chloride (PVC), but is not limited thereto. The spray heads 33 spray the effluent treating agent onto the packing material, thereby increasing a contact area between the gas or particles in the gas and the effluent treating agent on the packing material,
15 while wetting and rinsing the packing material to capture particles.

 The filter unit is connected to the upper opening 34 of the secondary wet scrubbing unit 30. The filter unit includes one or more filters and one or more spray heads. The filters are configured to capture and remove particles or fine dust in the effluent stream, such as PM_{2.5}. The spray heads may
20 spray the effluent treating agent to increase capture efficiency and to rinse the filters.

 The demisting unit is connected above the filter unit. In one example, the demisting unit includes one or more condensation plates. After the preceding water scrubbing processes, the effluent stream contains a certain

amount of moisture. To meet emission standards, the effluent stream entering the demisting unit flows through channels defined by the condensation plates to increase residence time and to contact the condensation plates, such that moisture is separated on the condensation plates. Accordingly, moisture in the effluent stream can be effectively removed to meet emission standards.

What is claimed is:

1. A head assembly, configured to be installed on a plasma reactor for treating gaseous pollutants, comprising:
 - a cover assembly disposed above a plasma reaction region, wherein the
 - 5 cover assembly comprises a top plate and a bottom plate, and a region for receiving a cooling fluid is provided between the top plate and the bottom plate, the bottom plate comprising one or more openings;
 - one or more plasma modules respectively connected to the plasma reaction region through the openings, each of the plasma modules comprising
 - 10 a microwave source configured to generate a microwave oscillation, a waveguide assembly coupled to the microwave source and configured to transmit the microwave oscillation, and a resonant cavity coupled to the waveguide assembly and configured to guide the microwave oscillation substantially along a waveguide direction, wherein the
 - 15 resonant cavity comprises a first chamber proximate to the waveguide assembly and a second chamber distal from the waveguide assembly, the second chamber receiving the microwave oscillation passing through the first chamber, the microwave oscillation reacting with a reaction gas to form a plasma field supplied to the plasma reaction
 - 20 region, wherein a formation orientation of the plasma field is along a first direction; and
 - one or more guiding conduit assemblies configured to guide an effluent stream from a semiconductor process to the plasma reaction region, wherein a flow direction of the effluent stream is along a second
 - 25 direction, the first direction intersects the second direction at an angle,

and the one or more guiding conduit assemblies are configured to generate a cyclone in the plasma field.

2. The head assembly of claim 1, wherein the plasma field is generated within a dielectric tube, the dielectric tube extends along the first direction to an inlet chamber, the guiding conduit assembly comprises a first inlet and a second inlet, the first inlet and the second inlet extend along the second direction into the inlet chamber, wherein the first inlet and the second inlet are disposed on an annular wall of the inlet chamber in an opposing and offset arrangement.
3. The head assembly of claim 1, wherein the plasma field is generated within a dielectric tube, the dielectric tube extends along the first direction to an inlet chamber, the guiding conduit assembly comprises a first inlet and a second inlet, the first inlet and the second inlet extend along the second direction into the inlet chamber, wherein the first inlet and the second inlet are disposed on an annular wall of the inlet chamber, and the inlet chamber comprises a deflector configured to partially block the first inlet and the second inlet so as to direct a flow of the effluent stream entering the inlet chamber.
4. The head assembly of claim 3, wherein the deflector comprises an inclined conical surface.
5. A reactor for treating gaseous pollutants, comprising:
one or more inlet modules, each comprising one or more guiding conduit assemblies configured to guide an effluent stream from a semiconductor process;

- one or more plasma modules in communication with the inlet modules,
each of the plasma modules comprising a microwave source
configured to generate a microwave oscillation, a waveguide assembly
coupled to the microwave source and configured to transmit the
5 microwave oscillation, and a resonant cavity coupled to the waveguide
assembly and configured to guide the microwave oscillation
substantially along a waveguide direction, wherein the microwave
oscillation reacts with a reaction gas to form a plasma field;
- a reaction module coupled below the inlet modules and the plasma
10 modules, wherein the reaction module comprises a plasma reaction
chamber, a bottom chamber located below the plasma reaction
chamber, and a cover assembly disposed at an upper opening of the
plasma reaction chamber, the plasma modules extending substantially
vertically through the cover assembly such that the guiding conduit
15 assemblies guide the effluent stream into the plasma reaction chamber,
wherein the cover assembly comprises a top plate and a bottom plate,
and a region is provided between the top plate and the bottom plate;
and
- a cooling module comprising a cooling fluid source and one or more
20 cooling conduits connected to the cooling fluid source, wherein the
cooling conduits are configured to supply cooling water to the region.
6. The reactor of claim 5, wherein the plasma reaction chamber
comprises an annular gap and a water reservoir in communication with
the annular gap, the water reservoir providing a water curtain flowing
25 downward along an inner wall of the plasma reaction chamber via the

annular gap.

7. The reactor of claim 5, wherein a formation orientation of the plasma field is along a first direction, a flow direction of the effluent stream is along a second direction, the first direction intersects the second direction at an angle, and the one or more guiding conduit assemblies are configured to generate a cyclone in the plasma field.
8. The reactor of claim 7, wherein the plasma field is generated within a dielectric tube, the dielectric tube extends along the first direction to an inlet chamber, the guiding conduit assembly comprises a first inlet and a second inlet, the first inlet and the second inlet extend along the second direction into the inlet chamber, wherein the first inlet and the second inlet are disposed on an annular wall of the inlet chamber in an opposing and offset arrangement.
9. The reactor of claim 7, wherein the plasma field is generated within a dielectric tube, the dielectric tube extends along the first direction to an inlet chamber, the guiding conduit assembly comprises a first inlet and a second inlet, the first inlet and the second inlet extend along the second direction into the inlet chamber, wherein the first inlet and the second inlet are disposed on an annular wall of the inlet chamber, and the inlet chamber comprises a deflector configured to partially block the first inlet and the second inlet so as to direct a flow of the effluent stream entering the inlet chamber.
10. The reactor of claim 9, wherein the deflector comprises an inclined conical surface.
11. A reactor for treating gaseous pollutants, comprising:

- a reactor comprising a reactor body, an internal region defined by the reactor body, and a partition separating the internal region from an exterior, wherein the partition comprises an outer cover plate and a space disposed within the reactor body and adjacent to the outer cover plate;
- 5 one or more guiding conduit assemblies configured to guide an effluent stream from a semiconductor process into the internal region of the reactor; and
- one or more plasma modules disposed above the reactor, each of the plasma modules comprising a microwave source configured to generate a
- 10 microwave oscillation, a waveguide assembly coupled to the microwave source and configured to transmit the microwave oscillation, and a resonant cavity coupled to the waveguide assembly and configured to guide the microwave oscillation substantially along a waveguide direction, wherein the resonant cavity comprises a first
- 15 chamber proximate to the waveguide assembly and a second chamber distal from the waveguide assembly, the second chamber receiving the microwave oscillation passing through the first chamber, and the microwave oscillation reacting with a reaction gas to form a plasma field in the internal region;
- 20 wherein the plasma field decomposes the effluent stream within the internal region, and the space is provided with a medium for reducing heat transfer such that a temperature of the partition is significantly lower than that of the internal region.
12. The reactor of claim 11, wherein a formation orientation of the plasma
- 25 field is along a first direction, a flow direction of the effluent stream is

along a second direction, the first direction intersects the second direction at an angle, and the one or more guiding conduit assemblies are configured to generate a cyclone in the plasma field.

13. The reactor of claim 12, wherein the plasma field is generated within
5 a dielectric tube, the dielectric tube extends along the first direction to an inlet chamber, the guiding conduit assembly comprises a first inlet and a second inlet, the first inlet and the second inlet extend along the second direction into the inlet chamber, wherein the first inlet and the second inlet are disposed on an annular wall of the inlet chamber in an
10 opposing and offset arrangement.
14. The reactor of claim 12, wherein the plasma field is generated within a dielectric tube, the dielectric tube extends along the first direction to an inlet chamber, the guiding conduit assembly comprises a first inlet and a second inlet, the first inlet and the second inlet extend along the
15 second direction into the inlet chamber, wherein the first inlet and the second inlet are disposed on an annular wall of the inlet chamber, and the inlet chamber comprises a deflector configured to partially block the first inlet and the second inlet so as to direct a flow of the effluent stream entering the inlet chamber.
- 20 15. The reactor of claim 14, wherein the deflector comprises an inclined conical surface.