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PLASMA GENERATING APPARATUS

Richard L. Bersin, Kensington, and Harvey James Beaudry, Fremont, Calif., assignors to International Plasma Corporation

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10 Claims

ABSTRACT OF THE DISCLOSURE

A plasma, or ionized gas, generating apparatus for reaction of the plasma with non-gaseous substances in a container, the apparatus having a support structure defined by spaced apart support plates which are interconnected by a plurality of posts. A pair of elongate electrode plates for each container is mounted on the support structure so that at least one of the plates can be moved toward and into engagement with the container for grasping the container and mounting it on the apparatus. The electrode plates have a concave configuration to grasp the container and include a layer of an electrically insulating material on the concave side to prevent short circuits between the electrode plates and the container and to facilitate the slideable insertion and removal of the container from between the plates. A supply manifold is carried by the support structure and includes a plurality of supply conduits for connection with the containers and the transmission of gas into the containers. An exhaust manifold is similarly carried by the support structure and connected with the container for removal of the gas and the plasma from the container.

RELATED APPLICATIONS

This application is related to the commonly owned, co-pending patent application bearing Ser. No. 753,683 filed Aug. 19, 1968, for Apparatus and Method for Generating Ionized Gas.

BACKGROUND OF THE INVENTION

This invention relates to plasma generating apparatus having a plurality of reaction chambers.

Prior art plasma generating apparatus with multiple reaction chambers generally have containers which define the reaction chambers and, separate therefrom, ionization chambers, or side arms, which extend transversely from and communicate with the reaction chambers. The ionized gas, or plasma, is generated in the ionization chamber and thereafter is caused to flow into the reaction chamber. This configuration of the containers requires a relatively complicated support structure for maintaining the containers in their proper orientation. The removal of the container from the apparatus is not possible unless the apparatus is generally disassembled, i.e. put in an inoperative condition.

In the above referenced co-pending patent application, there is disclosed a new plasma generating method and apparatus which, as compared to prior art machines, is greatly simplified. The generating apparatus disclosed in that patent application enables the ready removal of the containers without any disassembly of the apparatus and, in fact, without requiring the apparatus to be de-energized during the removal of a container and while such a container is removed from the apparatus. Prior art plasma generating apparatus are incapable of being employed with the apparatus disclosed in that patent application.

SUMMARY OF THE INVENTION

The present invention provides an apparatus for generating ionized gas, or plasma, and reacting the plasma with a non-gaseous substance in a container. Briefly, the invention comprises a support structure, a pair of electrode plates opposite and spaced apart from an axis of the container for positioning on the exterior of the container and for supporting the container, the electrodes being shaped generally so as to embrace the container with which they are associated, and mounting means connecting the electrode plates to the support structure. The mounting means may include an adjustable member permitting movement of at least one electrode plate of each pair toward and away from the other plate of the pair so as to grasp and support the container. Electrical conductors are connected with the plates and couple the latter with a radio frequency electric power source. A gas supply conduit is carried by the support structure, has a free end for connection to the container and provides for the transmission of gas to the container. An exhaust conduit for the withdrawal of gas from the container is connected thereto and is also carried by the support structure.

The plasma generating machine of the invention is particularly well adapted for use with reaction chambers constructed as described in the above referenced patent application and enables the effortless removal and installation of reaction chambers between sets of electrode plates. Such removal and installation is facilitated further by interposing a relatively frictionless layer of plastic material proximate one surface of each of the electrode plates. The electrode plates may also be spring biased toward the container with which they are associated so as to firmly grip and support the container while permitting removal and installation generally without tools.

The gas supply and exhaust systems, as well as the electrical distribution system of the present invention, are constructed for maximum safety; the gas supply and exhaust systems are embedded in hollow portions of the support structure to prevent damage to them, particularly if constructed of glass. These systems are positioned for ready accessibility during the installation of containers in the apparatus. The support structure includes apertures through which individual conduits for the containers of the supply and exhaust systems project to position and accurately locate the conduits with respect to the container with which they are associated.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a fragmentary front elevational view of a plasma generating apparatus constructed according to the present invention;

FIG. 2 is a fragmentary side elevational view, in section, and is taken on line 2—2 of FIG. 1;

FIG. 3 is an enlarged, fragmentary, sectional view taken on line 3—3 of FIG. 2.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIGS. 1 and 2, a plasma generating apparatus 8 comprises a support structure 10 and a plurality of containers 12 defining reaction chambers 14 and arranged side by side. The containers are elongate and have a generally cylindrical cross section. A forward end of the container is open to provide access to the reaction chamber and is covered by a lid 16. The con-

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tainer includes a gas intake conduit 18 and a diametrically opposed gas outlet conduit 20 for the continuous transmission of fresh gas into the reaction chamber and the withdrawal of used gas therefrom. For a more detailed description of the construction of the container and the reaction chamber the reader is referred to the above referenced co-pending patent application.

A pair of electrode plates 22 is provided for each container 12; and, in the embodiment shown, each plate has a circularly arcuate, concave surface 24 facing toward the axis of the container. One of the electrodes is biased toward the container, as more fully set forth below, so that the electrodes firmly grip the container and support it. A layer 26 of electrically insulating material is disposed between the exterior surface of the container and the concave surfaces of the electrodes to provide an electrical insulation and reduce friction between the plates and the container when the latter is moved axially between the plates. It is presently preferred to construct layer 26 of a plastic marketed under the trademark Teflon of the Du Pont de Nemours Company of Wilmington, Delaware. Teflon combines particularly good insulating characteristics with a very low co-efficient of friction. Other, similar materials can, of course, be substituted.

Referring to FIG. 3, layer 26 of insulating material is a sheet of a length equal to that of electrode plate 22 which has a curvature equalling that of concave surface 24 of the electrode plate. The sheet includes a pair of apertures 28 which are aligned with bolt holes 30 in the electrode plates and through which a flat head threaded bolt 32 extends. The bolt is constructed of an electrically non-conductive material, such as plastic, and is engaged by a nut 34 to secure the sheet to the electrode plates. This provides an economic connection between the insulating sheet and the electrode plate, permits the ready replacement of the insulating sheet should it become damaged, and maintains the electric insulation between the container and the electrode plates.

Referring again to FIGS. 1 and 2, support structure 10 includes a pair of spaced apart upper and lower plate members 36 and 37, respectively, each being constructed of a pair of elongate, L-shaped brackets 38 and 40, the short legs of which are spaced apart, parallel and face each other. A U-shaped channel 42 extends over the length of brackets 38, 40 of upper plate members 36, and is secured to the short legs of the L-shaped members by threaded bolts. The web of channel 42 protrudes a short distance beyond a plane defined by the long legs of the members. A second U-shaped channel 44 is disposed adjacent the free ends of the short legs of L-shaped brackets 38 and 40 of both the upper and lower plate members 36 and 37. Channels 44, however, are inverted with respect to channel 42; and each channel 44 is secured to the short legs of L-shaped brackets 38, 40 with which it is associated by threaded bolts. Thus, the short legs of the L-shaped brackets of upper plate member 36 together with channels 42 and 44 proximate thereto define an elongate, hollow space or chamber 46 extending over the full length of the L-shaped brackets and U-shaped channels associated with upper plate member 36.

The other plate member 37 is constructed identically to plate member 36 except that it does not include the U-shaped channel 44, so that the short legs of the L-shaped brackets 38, 40 and U-shaped channel 42 define an open ended hollow space or duct 48 which also extends over the full length of the brackets and the channel.

Referring to FIG. 2, each L-shaped member includes a protrusion 52 which extends from the free end of the long legs normal to the plane defined by the long legs for a distance equal to the distance the web of U-shaped channel 42 protrudes beyond that plane.

Plate members 36, 37 are interconnected by electrode plate support posts 50 which are of a unitary construction. Ends of the posts are secured to L-shaped brackets 38 of the respective plate members by threaded bolts. The

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spacing between adjacent posts is twice the spacing between adjacent containers 12 for purposes to be described hereinafter. The plate members and the posts are firmly secured to each other and can be inserted into a housing 53 (shown in FIG. 2 only) for the plasma generating apparatus 8. The housing in turn may rest against the web of the U-shaped channel and the protrusions 52 of the L-shaped brackets without interference between the housing and the bolts securing posts 50 to the plate members. Suitable fasteners such as threaded bolts connect the housing and the plate members.

The construction of the plate members 36, 37 is highly economical since their components are interchangeable. More importantly, however, hollow spaces, or chamber and duct 46 and 48, respectively, together with the short legs of L-shaped brackets 38 and 40 protect and position components of the apparatus as set forth below.

The length of plate members 36, 37 and the number of posts 50 is, of course, dependent upon the number of containers 12 disposed in the apparatus. For example, if the apparatus is equipped with six reaction chambers, four posts 50 are provided and the length of plate members 36 and 37 is about four times the spacing between the posts. Any desired number of reaction chambers can, of course, be installed in the apparatus.

Referring to FIGS. 1 and 2, an electrode plate secondary support post 54 is disposed intermediate each adjacent pair of posts 50 and comprises a pair of aligned ceramic insulators 56 respectively secured to plate members 36 and 37 by threaded bolts. An elongate, threaded bar 58 is mounted between the insulators parallel to posts 50 and perpendicular to the axes of the adjoining containers 12. A mounting member or block 60 has a central aperture 62 of a diameter greater than that of threaded bar 58 and is slipped over the bar so that the mounting member is movable along the bar. A knurled nut 64 threadably engaging bar 58 is disposed on each side of the block to position the block on the bar and secure it thereto.

An elongate leaf spring 66 is disposed adjacent each side of the block facing an electrode plate 22 and is secured to the block at the center of the spring by a suitable fastener such as a machine screw (not shown), for example. Each leaf spring is arcuate over its length and its concave side faces the adjacent electrode plate. The ends of the springs include U-shaped cutouts 70 for engagement by a threaded bolt 72 extending from the side of electrode plate 22 opposite container 12. A nut 74 is threaded onto bolt 72 but is not tightened against the spring and the electrode plate (see FIG. 3) to permit relative movement between bolt 72 and the spring within the confines of cutout 70.

The second electrode plate of each pair of plates is secured in a relatively fixed manner to a post 50 by a threaded bolt 76 depending from the electrode plate on the side opposite concave surface 24. Bolt 76 engages a threaded bolt hole (not shown) in the post or is secured thereto by a nut (not shown) on the interior of the post.

The construction of posts 50 and 54, electrode plates 22, mounting blocks 60, and leaf springs 66 does not require high accuracy for proper operation of the assembly and thus eliminates close tolerances and high manufacturing costs. To illustrate in greater detail, one of each of electrode plates is secured to a post 50, the second electrode plate is secured to leaf spring 66 with bolts 72 and nuts 74; and the two plates are aligned by moving the second electrode plate along the threaded bar 58 of post 54 with knurled nuts 64 until the two electrode plates are in alignment. Container 12 can be installed in the apparatus by slideably pushing it between the plates. The ends 68 of leaf spring 66 are sufficiently offset from block 60 to assure the engagement of the container and the electrode plates. The electrode plate secured to the leaf spring thereby exerts a force against the container to secure the latter to the electrode plates and the support structure

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10. Tolerances in the configuration of the container and the spacing between the posts are compensated for by the laterally movable electrode plate secured to the leaf spring. Thus, neither the relative positioning of posts 50 and 54 nor the dimensional accuracy of container 12, spring 66, or electrode plates 22 is of great importance, since the spring mounted electrode plate can compensate for all commonly encountered manufacturing and assembly tolerances.

Referring to FIG. 2, and assuming that the container is constructed as described in the above referenced co-pending patent application, its intake conduit 18 faces away from lid 16 parallel to the axis of the container while its outlet conduit faces in the same direction but is angularly inclined with respect to the axis. To connect the gas inlet conduit with a supply of gas (not shown) a supply conduit 78 is provided which is positioned to be aligned with inlet conduit 18 when the container is disposed between the electrode plates. A free end of the supply conduit includes a flexible hose coupling 80, such as a length of tubular polyvinylchloride (PVC), for connection of the supply conduit with the inlet conduit. Slight misalignments in the positioning of the two conduits are compensated for by the flexible coupling. The other end of the supply conduit terminates in a supply manifold 82 disposed in hollow space 46 and carried by U-shaped channel 44 of plate member 36. The U-shaped channel 44 includes cut-outs 84 to permit passage of supply conduits 78 from manifold 82 to inlet conduit 18 of container 12. The cut-outs in the channel are so positioned that the supply conduits are automatically aligned with the inlet conduits of the container when placed in the cut-outs to eliminate tedious assembly line-ups between the two or complicated positioning devices. The supply manifold extends over substantially the full length of plate member 36 to permit its connection with each of the reaction chambers 14 of the apparatus. To prevent deterioration of the supply conduit and manifold from chemically corrosive materials, the two are preferably constructed of glass. Although glass is susceptible to breakage from even a slight impact, the manifold is well protected from virtually all foreign objects within the hollow space or chamber 46.

Still referring to FIG. 2, an exhaust manifold 86 communicates with a vacuum pump (not shown) through an opening 88 in the exhaust manifold and with an exhaust conduit 90 for each container 12 through a sealed connection 91. Known clamps (not shown) grasp flanges 86a and 90a of the exhaust manifold and conduits, respectively, to maintain connection 91 in firm engagement. The exhaust conduit extends generally parallel to the axis of the container from the manifold to outlet conduit 18. Each exhaust conduit 90 is supported by semi-circular cut-outs 94 in the short legs of L-shaped brackets 38, 40. Cut-outs 94 additionally position each exhaust conduit with respect to its associated container 12 in the same manner as cut-outs 84 position supply conduits 78. Rubber or plastic grommets 96 overlying the edges of the L-shaped brackets defining the cut-outs protect the exhaust conduits from possible damage. A clamp 93 grasps each exhaust conduit between the cut-outs 94 and is tightened with bolts 95 anchored to channel 44 between the L-shaped brackets 38, 40 of plate member 37. Clamps 93 firmly secure the exhaust conduits to the plate members in cut-outs 94 and thereby also connect the exhaust manifold with support structure 10. Tedious alignments of the exhaust conduits during the assembly of the apparatus and/or costly positioning devices for the exhaust conduits are thereby eliminated since the conduits must merely be placed in the cut-outs for proper positioning.

The end of the exhaust conduit adjacent outlet conduit 18 is angularly inclined with respect to the axis of the container and includes a frusto-conical connecting surface 92 for connection to the outlet conduit as more fully

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described in the above referenced co-pending patent application.

The positioning of the free ends of supply and exhaust conduits 78, 90 is, of course, determined by the construction of container 12 and the relative position of its intake and outlet conduits 18, 20. If the container is constructed as set forth in the above identified, co-pending patent application, then the axes of the supply and exhaust conduits are aligned with the axis of container 12, as illustrated in FIG. 1.

Referring to FIG. 2, pairs of aligned elongate ceramic insulators 100 are secured to plate members 36 and 37, respectively, by threaded bolts extend from the plate members toward each other. Elongate, cylindrical bus bars 98 are mounted to free ends of the ceramic insulators by threaded bolts 102; and such bus bars extend over the full length of the plate members adjacent the closed ends of containers 12. The bus bars are electrically connected with a radio frequency (RF) generator 104 in a known manner.

A relatively wide, L-shaped terminal strip 106 is secured to each electrode plate 22 with a threaded bolt 108 and a nut 110. The strip is twisted 90° at 112 to change the orientation and direction of such strip toward one or the other of the bus bars, thus connecting each one of the pair of the electrode plates to a different one of the bus bars.

The free end of each terminal strip includes a clamp 114 secured to the terminal strip with a flexible connector 116 and having a pair of jaws 118 of a semi-circular configuration for grasping the exterior of the bus bar. Means, such as a threaded bolt 120 in engagement with the jaws, or a suitable spring (not shown) between the jaws, is provided for securely tightening the clamp to the bus bar and establishing an electrical connection between the two which is capable of transmitting the RF signals. It will be noted that the clamps are freely moveable with respect to their terminal strips by virtue of flexible connector 116 to facilitate the ease with which they are secured to and removed from the bus bars; and to provide flexibility when the moveable electrode plate is urged toward container 12.

Turning now to the operation of the plasma generating apparatus 8, the support structure is first assembled, the electrode plates 22 are connected with posts 50 and 54, supply and exhaust conduits 18, 20 and manifolds 82, 86 are placed in position, and clamps 114 at the end of terminal strips 106 of the electrode plates are connected with their respective bus bars. Containers 12 are now aligned with sets of electrode plates and moved in the direction of their axis into the space between opposing pairs of electrode plates. This movement automatically causes the engagement of the exterior surface of the container by the leaf spring 66 biased electrode plates whereby the container is firmly grasped, i.e. the biased electrode plate pushes the container into engagement with the fixed electrode plate, to thereby mount the container to support structure 10 and apparatus 8. The slideable movement between the container and the electrode plates is facilitated by the low friction, insulating plastic sheet 26 which also permits rotational movements of the container to align inlet and outlet conduits 18 and 20 with the supply and exhaust conduits 78 and 90. The axial movement of the container is now continued until the free end of inlet conduit 18 engages hose coupling 80. At the same time the frusto-conical mating surface (not shown) of end outlet conduit 20 engages the frusto-conical connecting surface 92 of the corresponding supply conduit 90 to thereby complete the installation of the container.

It will be noted that support structure 10, containers 12, the supply and exhaust conduits 78, 90, supply and exhaust manifolds 82, 86, and bus bars 98 can be mounted to and removed from housing 53 as a unit. This is particularly desirable where the plasma generating ap-

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paratus is to receive containers (not shown) of different configurations as, for example, a single, relatively large container (not shown) that is positioned transversely to containers 12 and parallel to support members 36, 37. Such a container can be used for reacting large samples with the plasma and requires its own support structure. Its installation, however, in housing 53 is quick and economical and adapts the plasma generating apparatus for widely divergent applications.

To operate the plasma generating apparatus, lid 16 is secured to container 12, the pressure in reaction chamber 14 of the container is pumped down to attain the desired vacuum, and gas from a suitable supply (not shown) is introduced into the chamber through supply manifold 82, supply conduit 78 and inlet conduit 18. The RF generator 104 is actuated to energize the electrode plates 22 and thereby establish an electrical RF field in the space between opposing electrode plates and thereby ionize the gas in the chamber as more fully described in the above-referenced co-pending patent application. At the same time, gas is withdrawn from the chamber through outlet conduit 20, exhaust conduit 90 and exhaust manifold 86 at the same rate at which gas is introduced into the chamber.

One or more of the containers 12 can be removed from the apparatus at any time. For that, the container is simply moved away from the supply and exhaust conduits in an axial direction until it is disengaged from the electrode plate. The apparatus can continue to operate even while one or more of the containers is removed therefrom by closing the open end of the corresponding supply end exhaust conduits with a suitable plug (not shown).

What is claimed is:

1. An apparatus for conducting chemical reactions between a reactive gas and a non-gaseous substance in an RF generated electrodeless discharge comprising:

a cylindrical wall container defining a zone for conducting said reaction;

an inlet and an outlet associated with said container to provide fluid communicating passages with said zone, said inlet and outlet each having terminal portions away from said container;

a support structure;

a supply conduit carried by said support structure in fluid communication with means to supply said reactive gas including a terminal portion for hermetically engaging said inlet terminal portion;

an exhaust conduit carried by said support structure including a terminal portion for hermetically engaging said outlet terminal portion;

means removably supporting said container for conducting said discharge including:

a pair of opposed electrodes shaped to embrace contiguously the cylindrical sides of said container and permit axial movement thereof while embraced by said electrodes;

mounting means on said support structure fixedly positioning one of said electrode plates relative to said conduits; and adjustable mounting means including a flexible member for supporting the other electrode plate biased transversely of the longitudinal axis of said container and being urged against the wall thereof, whereby said container is frictionally supported by said electrode plates and positionable so as to hermetically engage said inlet and outlet terminal portions with said supply and exhaust conduit terminal portions, respectively, upon axial movement of said container;

means to connect said plates to a source of RF energy; and

means to adjust the reactive gas pressure within said container.

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2. Apparatus according to claim 1 wherein further said adjustable mounting means comprises an elongate post secured to said support structure, said post being spaced from the longitudinal axis of the container and oriented transversely thereto;

a mounting member disposed on the post; and said flexible member provides attachment means to secure the mounting member to the one electrode plate adjacent thereto.

3. Apparatus according to claim 2 and wherein further said elongate post is substantially normal to the longitudinal axis of the container; and

vertical adjustment and carrying means movably secured to said post to adjustably hold said mounting member therealong.

4. Apparatus according to claim 2 and wherein further said flexible member comprises a leaf spring secured to the mounting member and operably engaged with the adjacent one of said electrode plates so as to urge the last said electrode plate toward the container plate, and the sides of the electrode plates facing the container therebetween include a layer of an electrically insulating material for facilitating slidable movement parallel to the axis between the container and the plates.

5. Apparatus according to claim 1 and further including a plurality of laterally spaced sets of electrode plates for receiving between each pair thereof one of a plurality of containers, wherein the support structure includes a pair of opposed plate members positioned parallel to a plane defined by the longitudinal axes of the containers, with at least one of the plate members defining a channel and a manifold disposed in the channel for support and protection of the manifold, the manifold being in fluid communication with one of the conduits through openings in walls defining the channel.

6. Apparatus in accordance with claim 5 wherein further said other plate member also defines a channel, and a second manifold disposed in last said channel for support and protection of the second manifold, said second manifold being in fluid communication with the other of the conduits through openings in the walls defining last said channel.

7. The apparatus in accordance with claim 1 characterized by the container being of a generally circular cylindrical cross section and wherein further said electrode plates are concave in transverse section.

8. Apparatus according to claim 1 including a plurality of laterally spaced sets of electrode plates for receiving a like plurality of containers in substantial parallel alignment, an elongate bus bar mounted on insulators secured to the support structure and positioned transversely to the longitudinal axes of the containers, and wherein the electrical conductors include electrical clamp connectors demountably secured to the bus bar.

9. Apparatus for generating ionized gas and reacting the gas with non-gaseous substances in a plurality of cylindrical containers, comprising:

(a) a support structure having a pair of parallel, spaced apart plate members interconnected by a plurality of first posts and a second post spaced from the first posts secured to the plate members, and electrically insulated from the plate members and the first posts,

(b) elongated first electrode plates secured to the first post, the first electrode plates having a concave surface facing said second post, adjacent thereto,

(c) second electrode plates secured to the second posts opposite the first electrode plates, the second electrode plates having a concave surface facing the first electrode plates, the adjacent first and second electrode plates forming sets defining a common axis and being spaced apart to permit placement of the containers between such sets of electrode plates,

(d) a layer of an electrically insulating material on the concave side of the electrode plates,

(e) a supply manifold carried by the support structure

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and having a supply conduit for each set of electrode plates for transmission of gas to the container, the supply manifold being disposed in and protected by hollow portion of the support structure, the supply conduits being further disposed in openings of the support structure for positioning of the conduits relative to the sets of electrode plates,
(f) an exhaust manifold supported by the other plate member and having an exhaust conduit for each set of electrode plates for withdrawal of gas from the containers, and
(g) electrical conductors for coupling the electrodes with a source of electrical power.
10. Apparatus according to claim 9 including spring means connecting the second electrodes to the second posts to cause the second electrodes to move toward and away from the first electrodes and to be urged into sup-

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portive contact with the one of said cylindrical containers in operative position between said electrodes.

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JOHN H. MACK, Primary Examiner

15 N. A. KAPLAN, Assistant Examiner

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