



(12) **United States Patent**  
**Jacob et al.**

(10) **Patent No.:** **US 9,849,202 B2**  
(45) **Date of Patent:** **Dec. 26, 2017**

- (54) **PLASMA POUCH**
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- (\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 645 days.

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(21) Appl. No.: **13/619,019**

(22) Filed: **Sep. 14, 2012**

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(65) **Prior Publication Data**  
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(51) **Int. Cl.**  
**A61L 2/14** (2006.01)  
**H05H 1/24** (2006.01)

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(52) **U.S. Cl.**  
CPC ..... **A61L 2/14** (2013.01); **H05H 1/2406** (2013.01); **H05H 2001/2412** (2013.01); **H05H 2001/2418** (2013.01); **H05H 2001/2425** (2013.01); **Y10T 29/49147** (2015.01)

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(Continued)

(58) **Field of Classification Search**  
CPC ..... B01J 12/002; B01J 19/088; A61L 2/14; H05H 1/2406; H05H 2001/2425; H05H 2001/2412; H05H 2001/2418; Y10T 29/49147; B65B 55/12; H01J 37/32394; H01J 37/32568; H01J 37/32908; H01J 37/32798; C02F 1/78; A23L 3/34095  
USPC ..... 422/186.04, 186.21-186.23, 1-43, 186, 422/22-24; 204/158.2  
See application file for complete search history.

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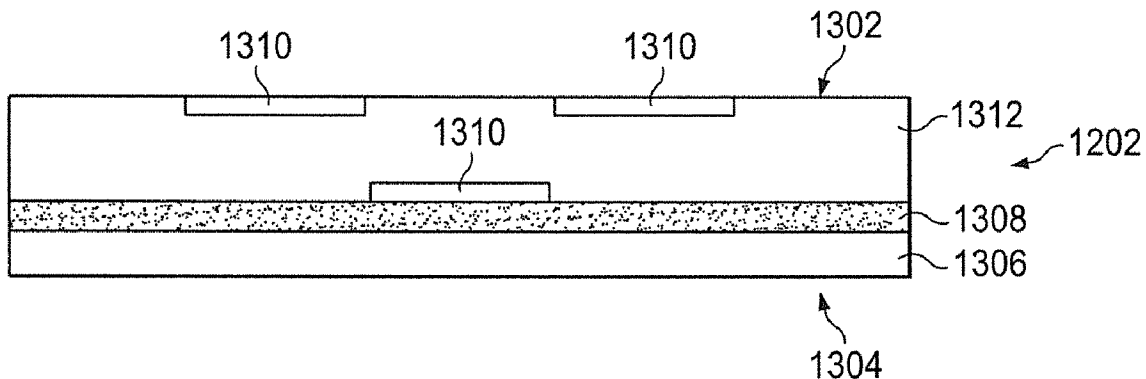
(57) **ABSTRACT**

A device with a pouch having a pouch wall with an inner side and an outer side, the pouch wall defining an interior of the pouch. A plurality of electrodes embedded in the pouch wall with at least one electrode partially exposed within the interior of the pouch. The plurality of electrodes generate plasma within the interior of the pouch in response to application of an voltage to the plurality of electrodes.

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**12 Claims, 11 Drawing Sheets**



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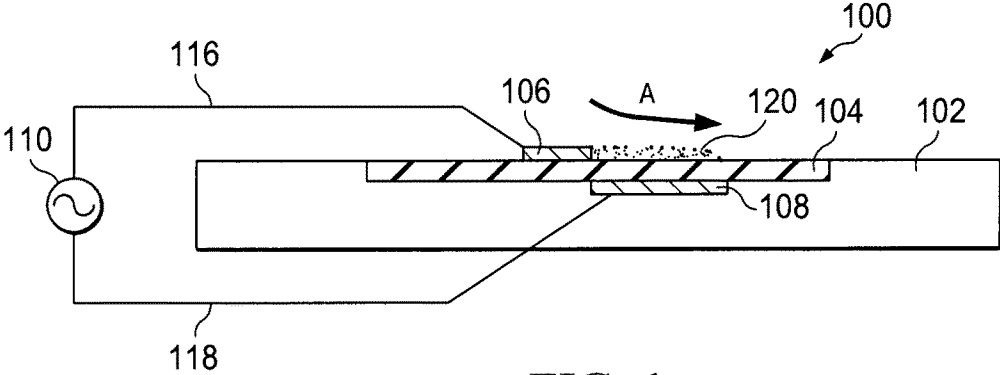


FIG. 1

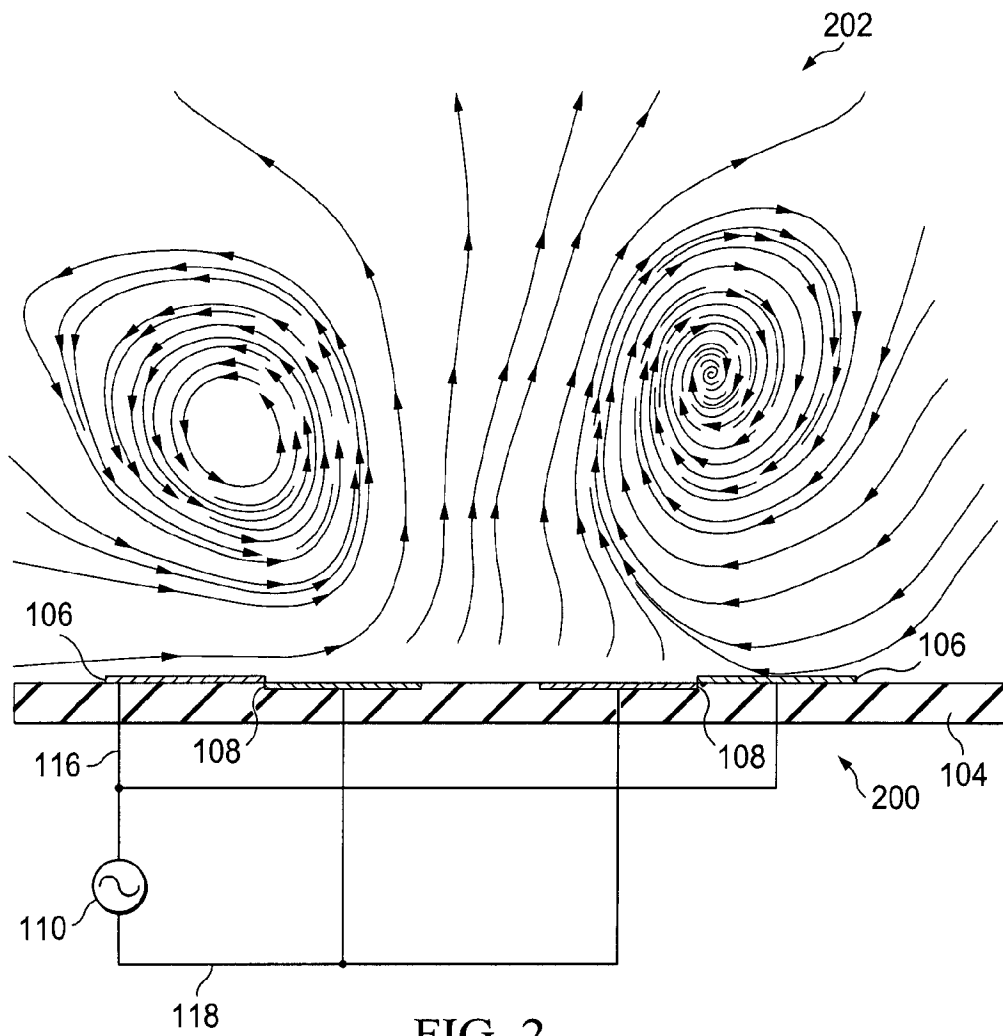


FIG. 2

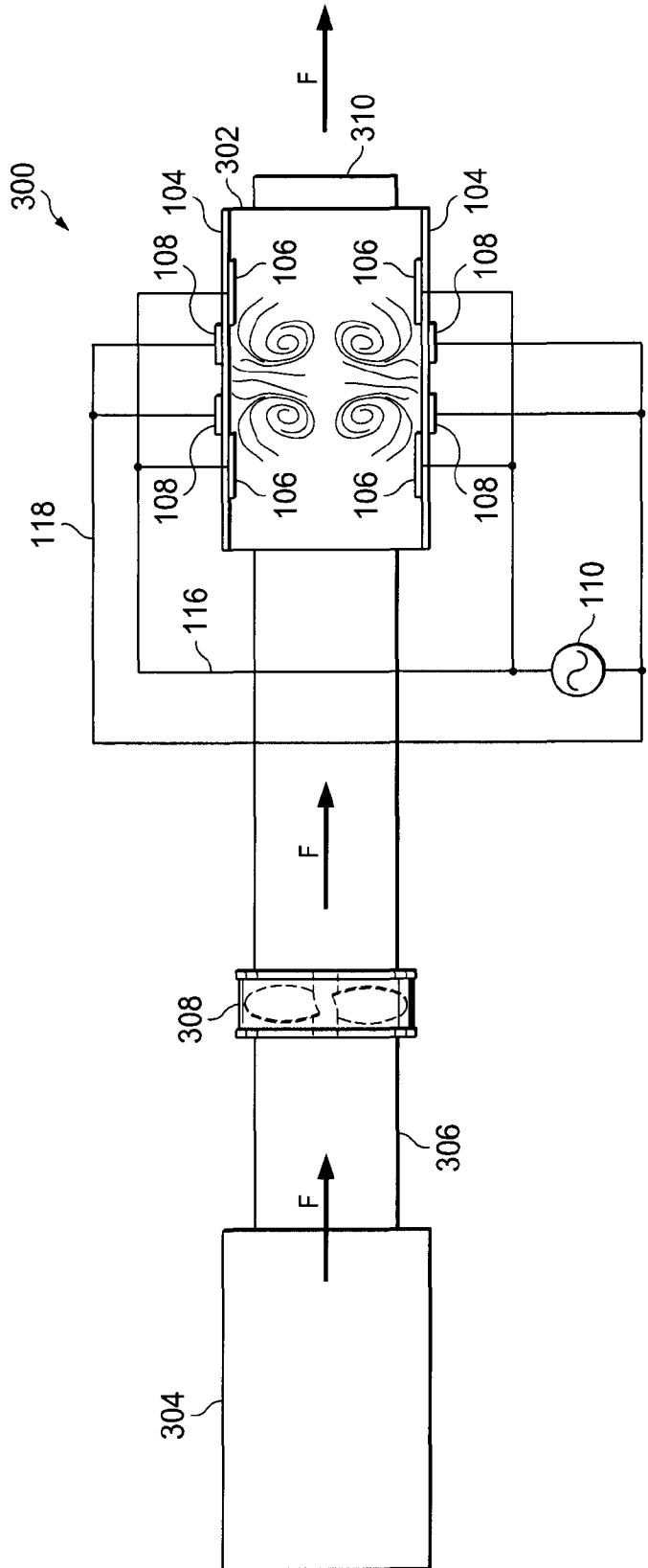


FIG. 3

FIG. 4

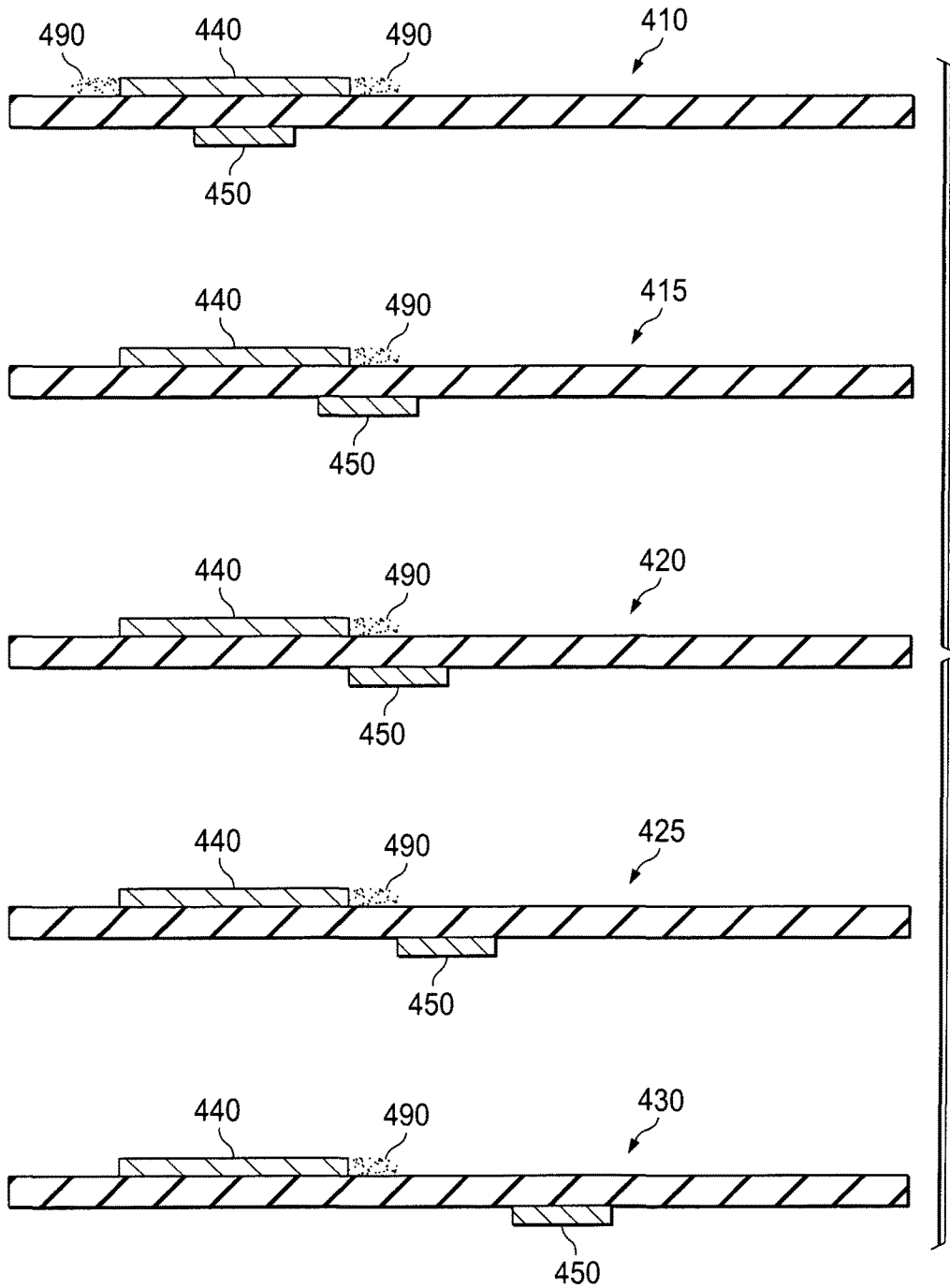
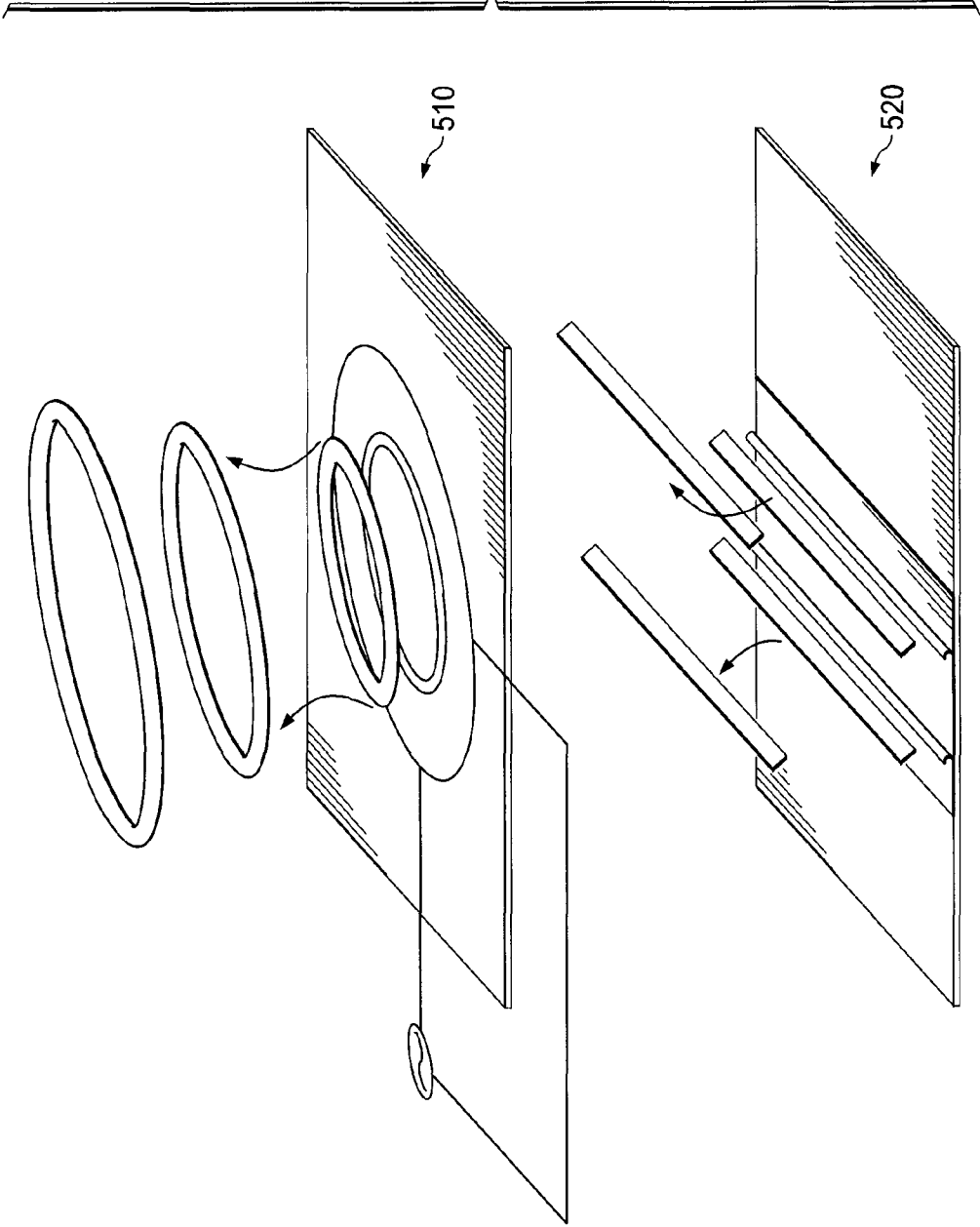


FIG. 5



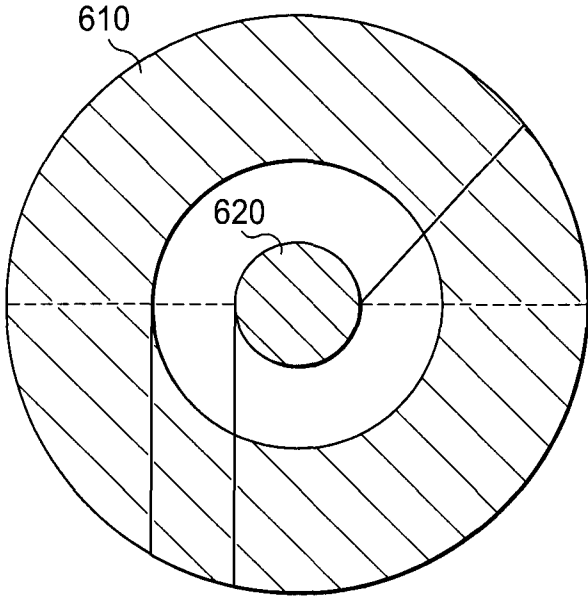


FIG. 6

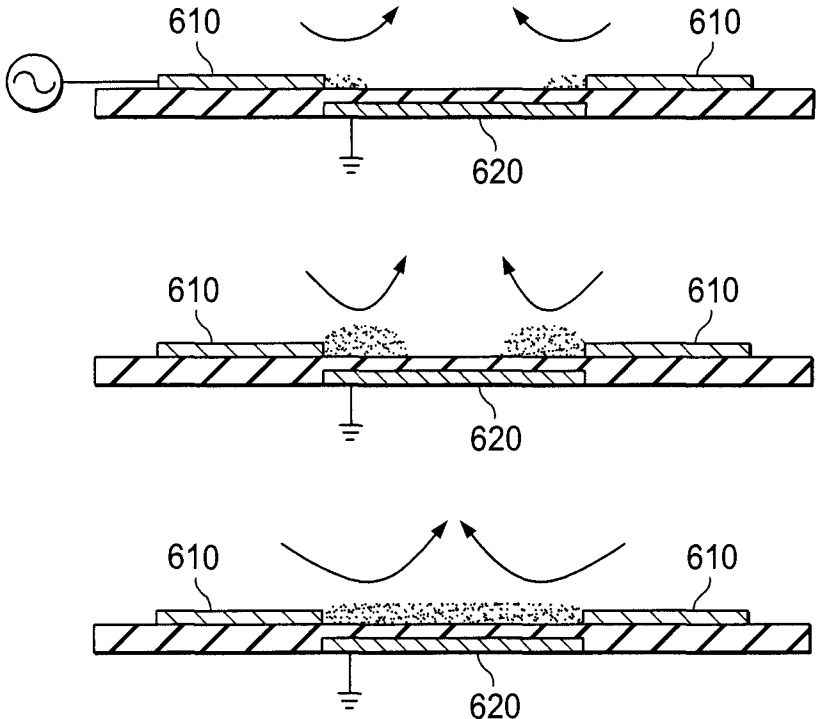


FIG. 7



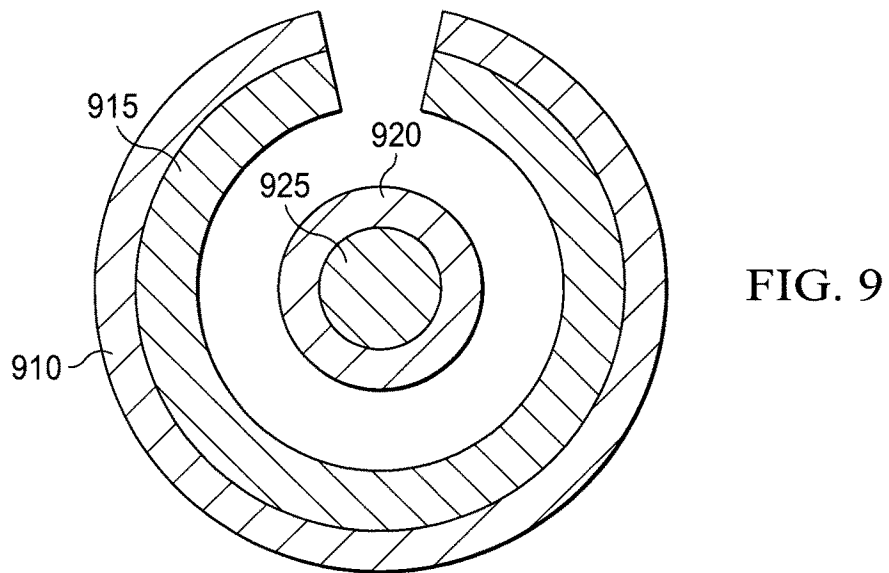
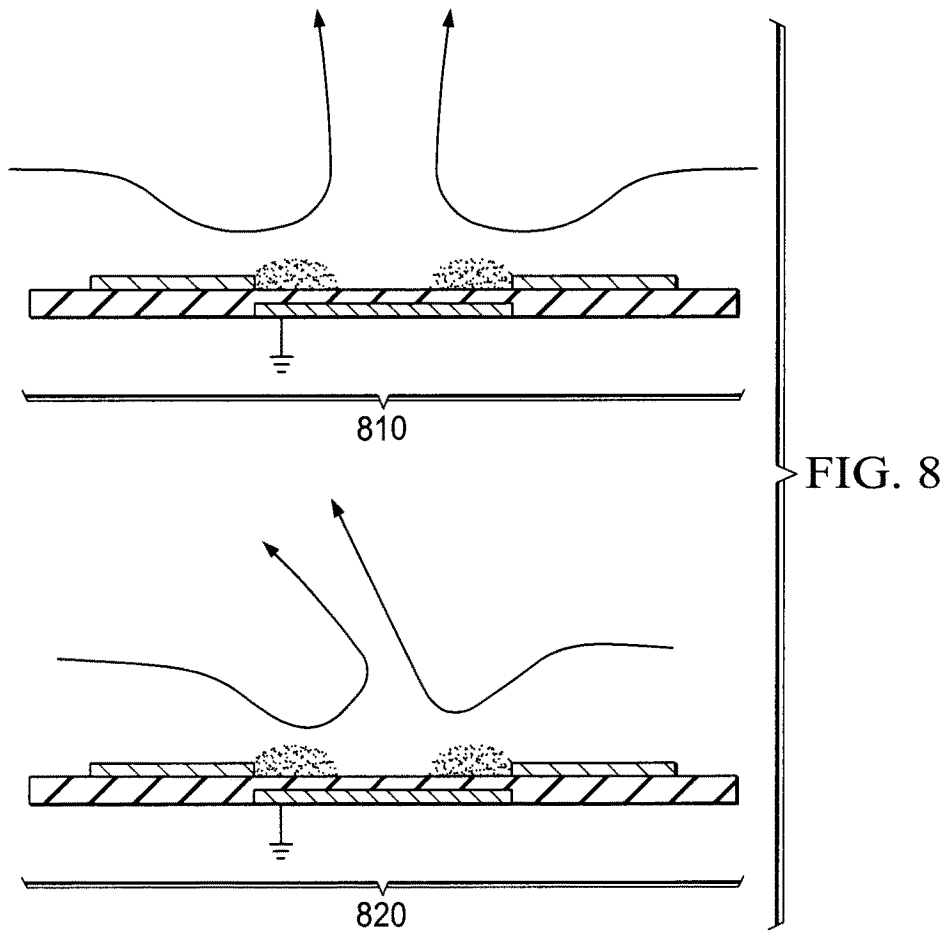


FIG. 9

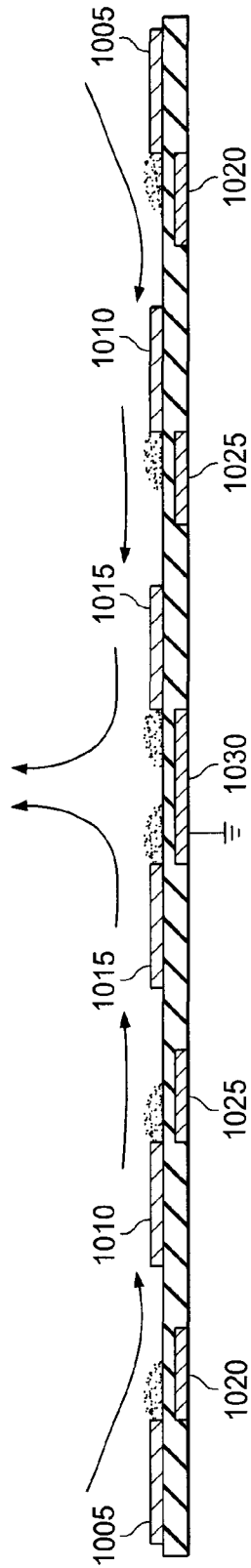


FIG. 10

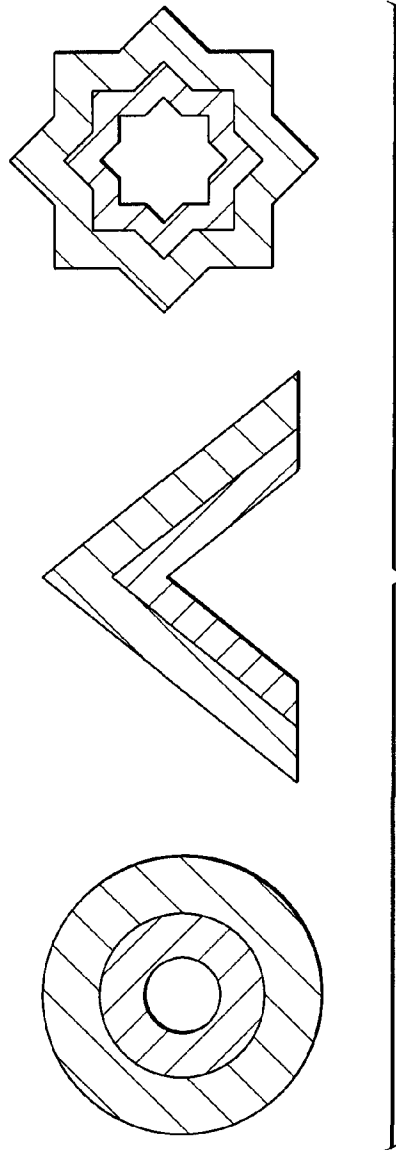


FIG. 11

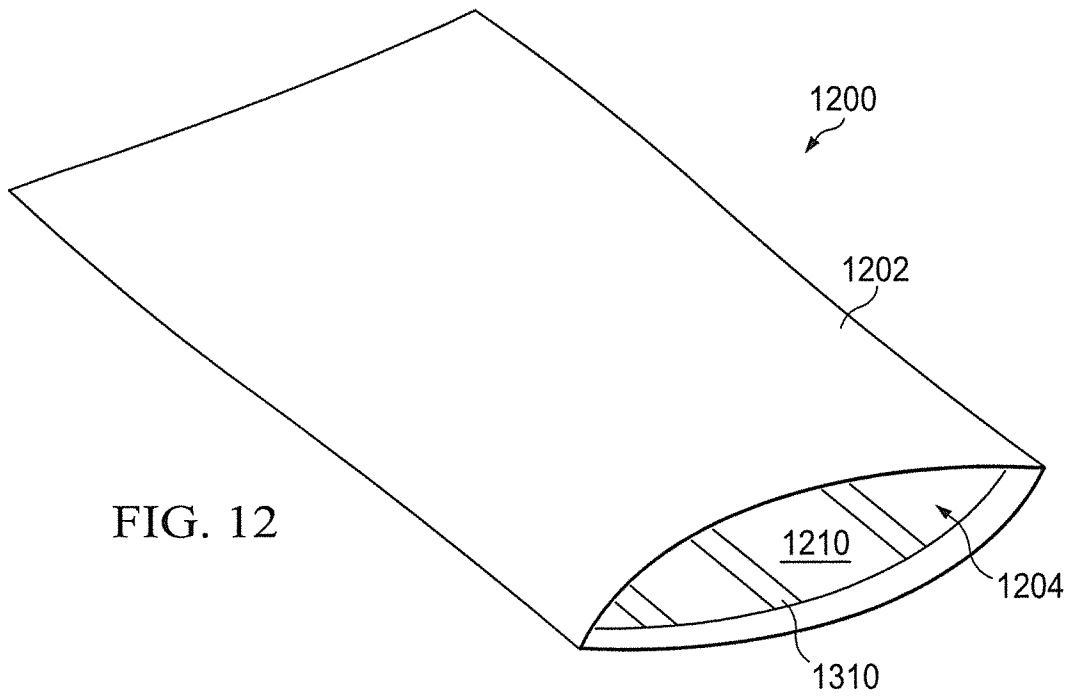
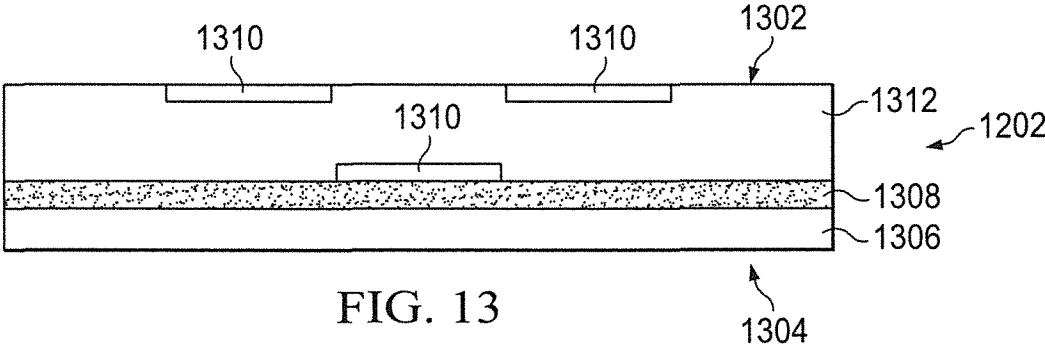


FIG. 12



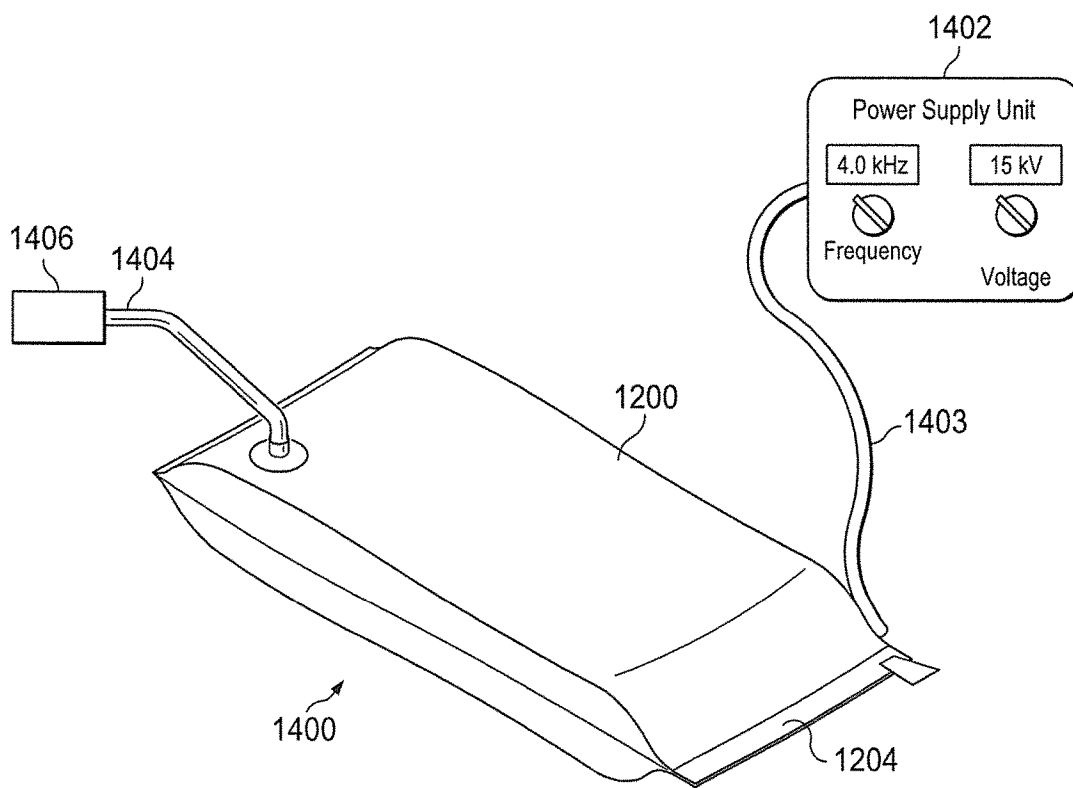


FIG. 14

## PLASMA POUCH

## FIELD OF THE INVENTION

This disclosure is related to plasma technologies in general and, more particularly, to plasma apparatus for biological decontamination and/or sterilization.

## BACKGROUND OF THE INVENTION

Plasma actuators are zero-net mass flux (ZNMF) devices that use atmospheric pressure electrical discharges. These discharges are from a class that includes corona discharges, dielectric barrier discharges (DBDs), glow discharges and arc discharges. Plasma is further known to be a sterilization medium for a number of biological agents through some combination of the mechanisms of heat, ultraviolet radiation, ionization, etc. However, the items to be sterilized must be placed within the plasma itself, possibly damaging the device to be sterilized and limiting the scope and efficacy of the sterilization volume.

What is needed is a system and method for addressing the above, and related, concerns.

## SUMMARY OF THE INVENTION

The invention of the present disclosure, in one aspect thereof, comprises a device with a pouch having a pouch wall with an inner side and an outer side, the pouch wall defining an interior of the pouch. The device includes a plurality of electrodes embedded in the pouch wall with at least one electrode partially exposed within the interior of the pouch. The plurality of electrodes generate plasma within the interior of the pouch in response to application of voltage to the plurality of electrodes.

In some embodiments, the pouch wall comprises a flame and shock resistant outer covering on the outer side of the pouch wall. The electrodes may be at least partially embedded in a dielectric medium on the inner side of the pouch wall. A substrate may interpose the outer covering and the dielectric medium. The device may include a power supply that supplies voltage to the electrodes for the generation of plasma.

The pouch may have a sealable opening. In some embodiments, the device includes an outlet hose passing from the inner side to the outer side of the pouch wall for evacuating gases within the pouch. A filter unit may be connected to the outlet hose.

The invention of the present embodiment, in another aspect thereof, comprises a device having a substrate, a dielectric medium on a first side of the substrate, and a plurality of electrodes affixed to the substrate that generate plasma on the first side of the substrate in response to application of an electric voltage. The device includes an outer covering on a second side of the substrate. The substrate, dielectric medium, and outer covering form a flexible wall such that plasma is generated on a first side of a wall and a second side of the wall is protected from plasma exposure.

In some embodiments, the flexible wall is configured as a pouch with an opening. The pouch may be configured to produce plasma on an interior thereof. In other embodiments, the pouch produces plasma on an exterior thereof. An outlet hose may pass from the inside to the outside of the pouch. The device may include a power supply electrically connected to the plurality of electrodes and providing a voltage thereto for the generation of plasma.

The invention of the present disclosure, in another aspect thereof, comprises a method including providing a substrate, providing a dielectric medium on a first side of the substrate, and providing a plurality of electrodes affixed to the substrate. The method includes providing an outer covering on a second side of the substrate. A flexible wall is formed from the substrate, dielectric medium, and outer covering. A pouch is formed using the flexible wall with an open end and having the outer covering on an outside of the pouch. The method may also include providing a voltage to the plurality of electrodes to generate plasma on an interior of the pouch.

In some embodiments, the method includes providing a sealable closure on the open end. An evacuation hose passing from the interior of the pouch to an exterior of the pouch may be provided. The method may include evacuating at least part of the air inside the pouch via the hose, and/or providing a plasma feed gas into the pouch via the hose.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of one embodiment of a plasma generating device according to the present disclosure.

FIG. 2 is a schematic diagram of another plasma generating device according to the present disclosure.

FIG. 3 is a schematic diagram of a plasma decontamination system according to the present disclosure.

FIG. 4 contains some example relative positions of upper and lower conductors that would be suitable for use with various embodiments the present disclosure.

FIG. 5 contains schematic illustrations of linear and annular examples of the present disclosure.

FIG. 6 contains additional details of an annual embodiment.

FIG. 7 illustrates relative motive force for some different configurations of the embodiment of FIG. 6.

FIG. 8 contains schematic illustrations of asymmetrical motive force that will typically be produced by the embodiment of FIG. 6.

FIG. 9 contains still another embodiment of the present disclosure wherein multiple annular electrodes are used.

FIG. 10 illustrates a cross sectional view of another annular embodiment of the present disclosure.

FIG. 11 contains schematic illustrations of some other configurations of the present disclosure.

FIG. 12 is a perspective view of a plasma pouch decontamination device according to the present disclosure.

FIG. 13 is an end cutaway view of the plasma pouch of FIG. 12.

FIG. 14 is a perspective view of a system employing the plasma pouch of FIG. 12 for decontamination purposes.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In various embodiments of the present disclosure a plasma actuator is used for biological decontamination. Some embodiments of the present disclosure are based on the one atmosphere uniform glow discharge or single dielectric barrier discharge concept of cold plasma generation.

Referring now to FIG. 1, a schematic diagram of one embodiment of a plasma generating device according to the present disclosure is shown. In the embodiment of FIG. 1, the device **100** includes a substrate **102** onto which the various other components described herein may be attached.

As will be explained in greater detail below, the substrate **102** could be a portion of a chamber or enclosure. A suitable substrate **102** would be a non-conductive, impermeable material that is resistant to high temperatures or gas species. Glass, acrylic or phenolic materials are examples of acceptable materials.

Integrated with the substrate **102**, or forming a part of the substrate **102**, is a dielectric layer **104**. The dielectric layer **104** could be formed, by way of example only, from any material with a low dielectric constant such as PTFE or kapton.

An electrode **106** is situated along a top surface of the dielectric layer **104**. A second electrode **108** is situated along a lower surface of the dielectric layer **104**. It can be seen that the electrodes **106**, **108**, are at least somewhat offset from one another along a length of the dielectric layer **104**. The electrodes **106** and **108** might be made of copper or any other material with suitable conductivity.

The electrode **106** attaches to a voltage source **110** by an electrical lead **116**. The electrode **108** attaches to the voltage source **110** by an electrical lead **118**. In the present embodiment, the voltage source **110** may include a power supply as well as any necessary transformers or circuit conditioning components to enable generation of plasma by application of sufficient voltage between the electrodes **106**, **108** on the surface of the dielectric layer **104**. In the present embodiment, a plasma region **120** develops between the first electrode **106** and the second electrode **108**. The plasma region **120** also provides a motive force for any adjacent gases in the direction of the arrow "A".

Various duty cycles and voltages may be utilized to generate plasma. In the present embodiment, various voltages, frequencies and duty cycles have been tested and found to be operational. By way of example only, these include voltages in the range of 5 to 50 kV at frequencies of 1,000 to 10,000 Hz at a 10% to 100% duty cycle at modulated frequencies of 1, 2, 5, 10, 100, 500 and 5000 Hz. It will be appreciated that various flow rates and associated decontamination characteristics can be generated by adjusting the duty cycle voltage and frequency of the applied voltage. In application, the limit is most likely to be the durability of the materials used to construct the device **100** and the available power supply. For example, if operating from commercial power, higher voltages may be available than if operating from battery power.

Referring now to FIG. 2, a schematic diagram of another plasma generating device according to the present disclosure is shown. The device **200** is similar in construction and operation to the device **100** of FIG. 1. In the present device, two upper electrodes **106** are attached opposite a dielectric layer **104**, and are offset from a pair of lower electrodes **108**. Electrical lead **116** attaches the upper electrodes **106** to the voltage source **110** and a lower electrical lead **118** attaches the lower electrodes **108** to the voltage source **110**.

In the present embodiment, it will be appreciated that, due to the configuration of the electrodes **106** relative to the electrodes **108**, flow regions that are pointed in substantially opposite directions will be achieved. Thus, each electrode pair **106**, **108**, will generate plasma as well as a motive force pointed inward according to FIG. 2. This will cause a swirling effect of any adjacent gases as illustrated by the exemplary flow lines **202**.

In FIG. 2, both of the upper electrodes **106** are shown attached to a common voltage line **116**. Similarly, the lower electrodes **108** are shown attached to a common voltage line **118**. Thus, in operation, in this embodiment the upper electrodes **106** will always be at the same voltage potential

while the lower electrodes **108** will likewise share a voltage potential. However, it is understood that other configurations are possible. For example, both of the upper electrodes **106** need not necessarily be operated at the same voltage level. Similarly, the lower electrodes **108** could be attached to different voltage levels. In this manner the device **200** may be operated in a pulsing fashion where the gas flow is first in one direction, and then in another. It will be appreciated that both of the aforescribed exemplary operating methods will result in a thorough mixing of gases next to and around the device **200**. Thus, over time the adjacent gases will be exposed to the plasma generated by the device and the air thereby decontaminated from biological agents.

Referring now to FIG. 3, a schematic diagram of plasma decontamination system according to the present disclosure is shown. The plasma decontamination system **300** comprises a plasma decontamination chamber **302**. This chamber **302** may have a plurality of inner electrodes **106** separated from a plurality of outer electrodes **108** by a dielectric layer **104**. The dielectric layer **104** may be enclosed by a substrate (not shown).

The inner electrodes **106** may attach to a voltage source **110** by a lead **116**. The outer electrodes **108** may attach to the voltage source **110** by a lead **118**. The plasma decontamination system **300** operates in a manner similar to those previously described in that voltages will be applied to the plurality of inner electrodes **106** and outer electrodes **108** generating plasma inside the plasma decontamination chamber **302**. The motive forces provided by the plasma generation will serve to mix and swirl gas within the plasma decontamination chamber **302** such that the gases inside of the chamber **302** may be substantially completely decontaminated from biological agents.

In some embodiments, the motive force for drawing contaminated air into the plasma decontamination chamber **302**, and expelling decontaminated air, will be entirely due to the location and configuration of the plasma generating electrodes **106**, **108** in and on the plasma decontamination chamber **302**. However, in other embodiments, a separate flow control system may be utilized that provides for selective introduction of contaminated gases into the decontamination chamber **302** from a contamination source **304**. The contamination source **304** could be naturally or otherwise occurring bacteria or viruses, medical waste, sewage or any number of sources which generate air containing bio-contaminants. In the present embodiment, the gases flow generally from the contamination source **304** in the direction of the arrows "F".

A conduit **306** is provided between the plasma decontamination chamber **302** and the contamination source **304**. A fan **308** may be provided that produces vacuum toward the contamination source **304**, and positive pressure toward the plasma decontamination chamber **302**. The fan **308** or other flow driving device may operate in an open-loop configuration or may be selectively activated such that air within the decontamination chamber **302** has sufficient time for exposure to plasma to achieve a satisfactory level of decontamination. An exit conduit **310** may be provided for moving the decontaminated gas away from the decontamination chamber **302**. In some embodiments, the exit conduit **310** will merely function as a selectively closeable valve to prevent air from escaping the decontamination chamber **302** until sufficiently and effectively decontaminated.

FIGS. 4 through 11 illustrate additional embodiments of the present disclosure. In FIG. 4, configuration **410** is an embodiment that operates to generate a plasma stream **490** on both sides of the upper conductor **440** at its periphery.

However, some embodiments tend to produce better results when the upper **440** and lower **450** conductors at least partially overlap, tends to produce better results (e.g., **410** and **415**). Further, and continuing with the examples of FIG. **4**, configurations such as **420** to **430** tend to show generally decreasing performance as compared with configuration **415**. Obviously, if the conductors are spaced sufficiently far apart the plasma generated will be negligible or zero.

FIG. **5** contains a schematic illustration of linear **520** and annular **510** embodiments. As can be seen, in the embodiments of this figure the motive force associated with the plasma stream is in an outward (upward by reference to this figure) direction, i.e., a “blow” embodiment. That being said, if the electrical leads are reversed, a downward/inward (i.e., a “suck”) embodiment can be created.

FIGS. **6** and **7** contain additional details of an annular embodiment. In the configuration of FIG. **6**, note that the amount of plasma generated and the corresponding motive force can be varied by increasing the voltage differential that is supplied to the electrodes **610** and **620** as is illustrated generally in FIG. **7**.

FIG. **8** is a schematic cross-sectional illustration of the embodiment of FIG. **7** that shows that, although the motive force is generally directed orthogonally away from (or toward) the dielectric material, in some configurations and at some points along the embodiment of FIG. **7** that the force may take a path that is non-orthogonal to the dielectric material.

FIGS. **9** and **10** are schematic illustrations of still other arrangements that are generally annular. FIG. **9** contains an illustration of an annular embodiment that includes two upper electrodes **910** and **920** and two lower electrodes **915** and **925**. Note that the electrodes **910** and **920** might be electrically isolated from each other or not. The same might also be said with respect to electrodes and **915** and **925**.

FIG. **10** contains a cross-sectional view still another annular embodiment, with upper electrodes **1005**, **1010**, and **1015**, and lower electrodes **1020**, **1025**, and **1030**. Note that in some embodiments (e.g., FIGS. **7**, **8**, and **10**) one or more electrodes, e.g., the lower electrode in these figures, is embedded in the dielectric.

FIG. **11** contains some further embodiments, e.g., annular, chevron, and hybrid. Those of ordinary skill in the art will readily be able to devise other shapes and arrangements that generate plasma according to the instant disclosure.

Note that, although in some embodiments the dielectric is a generally rectangular single planar surface, in other embodiments it might be round, polygonal, etc. Additionally, in still other embodiments the dielectric might be separated into two or more pieces that are interconnected by conductive material. In such an instance, the electrodes of the instant disclosure might be placed on the same or different pieces of the dielectric. The dielectric and/or associated electrodes might also be non-planar depending on the requirements of a particular application. Thus, for purposes of the instant disclosure it should be understood that the term “dielectric” is applicable to materials that are any shape, that are planar or not, and that might be divided into multiple pieces that are joined by conductive materials.

Further note that for purposes of the instant disclosure, the term “length” should be broadly construed to be any linear dimension of an object. Thus, by way of example, circular dielectrics have an associated length (e.g., a diameter). The width of an object could correspond to a length, as could a diagonal or any other measurement of the dielectric. The shape of the instant electrodes and associated dielectric are arbitrary and might be any suitable shape.

Still further, note that the voltages applied to the top and bottom electrodes will be different. It is important that the voltage differential between the electrodes be sufficient for the generation of plasma, e.g., about 5 to 50 kV as was discussed previously. The positive electrode can either be on the top or the bottom of the dielectric and the orientation might be varied depending on the direction it is desired to have the plasma stream move.

Finally it should be noted that remembered that the term “offset” as used herein should be broadly construed to include cases where there is no overlap between the electrodes (e.g., configurations **425** and **430**) as well as cases where there is substantial overlap (e.g., configuration **410**). What is important is that the edges of the upper and lower electrodes not be completely coincident, e.g., one electrode or the other should have a free edge (or part of an edge) that does exactly overlay the corresponding electrode on the opposite surface.

Referring now to FIG. **12** a perspective view of one embodiment of a plasma pouch decontamination device according to the present disclosure is shown. The pouch **1200** represents an application of the plasma generation devices disclosed herein. The pouch **1200** may be constructed in various sizes to allow sterilization of differently sized articles. For example, the pouch **1200** can have multiple compartments like a piano file, and/or it can be constructed to substantially conform to the geometric outline of the object device to be disinfected or sterilized. In other examples, the pouch **1200** can be produced as a mitten. A mitten or glove configuration may be constructed “inside out” such that plasma is generated on the exterior (e.g., for hand held decontamination of instruments). Some embodiments will provide a sheath-like sterilization pouch, which can be used to decontaminate the surfaces of long, serpentine bodies such as those of catheters and other devices.

The pouch **1200** may comprise a body portion **1202** that may be folded around on itself to create an interior **1210** of the pouch **1200**. The body portion **1202** may be sealed at all but one edge that forms an opening **1204**. The opening **1204** allows for insertion and removal of articles to be sterilized. Within the interior **1210** of the pouch **1200** a plurality of plasma-generating electrodes **1310** can be seen. These electrodes **1310** may cover a portion, or substantially all, of the interior **1210** of the pouch **1200**.

Referring now to FIG. **13**, an end cutaway view of a portion of the plasma pouch **1200** is shown. The body portion **1202** can be seen to comprise an inner side **1302** corresponding to the interior **1210** of the pouch **1200**, and an outer side **1304** corresponding to an exterior of the pouch **1200**. The outer side **1304** may be covered by a flame and shock retardant material **1306** comprising an outer layer. This material **1306** may be similar to, or the same as, material utilized in fire resistant blankets. This may help to prevent any damage due to electricity or plasma to any objects or supporting surfaces outside the pouch **1200**. The material **1306** may also protect against shorting or burnout of interior dielectric material.

A substrate **1308** may be provided under, or next to, the outer layer material **1306**. The substrate **1308** may comprise materials such as Teflon® or polyethylene film. The substrate **1308** seals at least some of a plurality of electrodes **1310** against contact with air, and thus prevents generation of plasma on sealed surfaces. The pattern of the electrodes **1310** in the pouch can also implement various geometries (e.g., as discussed above). Thus, flow within the pouch **1200** can be controlled based on electrode geometry. In some



embodiments, metallic tape or etched powdered electrodes may be used due to their flexibility.

The electrodes **1310** are restrained in a dielectric medium **1312**. In some embodiments, the medium **1312** is a flexible film. This provides flexibility for the pouch **1200** and increases the number of geometries of electrodes that can be generated. The medium **1312** may range from less than 0.005 inches to about 0.010 inches in thickness. The thickness of the entire layer **1202** is only a few millimeters thick in some embodiments.

Referring now to FIG. **14**, a perspective view of a system **1400** employing the plasma pouch **1200** of FIG. **12** for decontamination purposes. The system **1400** employs a power supply **1402** that includes a transformer and a wall supply plugin. The power supply may provide a fixed voltage and frequency. In other embodiment, the power supply may have a variable voltage. In some cases the range will be from about 5 kV to 20 kV and may have a frequency between 600-5000 Hz. Switches and other controls may be provided for operation of the power supply **1402**.

The power supply **1402** is electrically connected to the plasma pouch **1200** and to the internal electrodes (e.g., **1310** of FIG. **13**). It is understood that a plurality of electrical leads may be combined into a single cord **1403** that enters the pouch **1200** (or pouch wall **1202**) for connection to the electrodes **1310**.

In operation, it may be useful to evacuate a certain amount of air from the pouch **1200** once the object to be decontaminated has been placed inside. This may result in a drop in the internal pressure of the pouch **1200** and/or a tendency for the pouch walls **1202** to adhere to the exterior of the contaminated object's surface. This helps reduce the distance between the plasma and the contaminated surface, allowing short lived species, such as Reactive Oxygen Species (ROS), to reach the surface of the object to be disinfected or sterilized.

The opening **1204** of the pouch **1200** may be sealable to prevent any gases and/or plasma generated species from escaping. This results in a complete inactivation mechanism. It also prevents a number of unwanted volatile gases and hazardous contaminants from escaping and potentially damaging nearby equipment or becoming a hazard to personnel.

Internally within the pouch **1200**, vortices are generated due to the body forces in surface discharges. This results in complete mixing of all the generated species to produce a very lethal "antimicrobial soup". The by-products generated in the process (e.g., ozone), may be ventilated out through a filter unit **1406** attached to outlet hose **1404**. Activated carbon is one filter media that may be used. Other reducing agent embedded filters may also reduce byproducts such as ozone to a less harmful form. In a similar fashion number of other materials can be used to adsorb other by-products such as NOx.

The pouch **1200** and/or the entire system **1400** may also be used for the purpose of cleaning surfaces through etching of both organic and inorganic molecules. Gaseous mixtures such as O<sub>2</sub> and CF<sub>4</sub> have a high etching ability when used as feed gas for plasma instead of air. In one embodiment, they are injected into the pouch **1200** via outlet hose **1404**. Valving (not shown) may be utilized to allow the same hose **1404** to be used for evacuation of gases and by product and the introduction of gases into the pouch **1200**.

The pouch **1200** may have a number of sensors and actuators to boost its performance. For example, the pouch **1200** may contain proximity sensors and/or electric relays to shut down the discharge if a short or burn-out is detected.

Ozone and other particulate concentration sensors may be used to detect leaks in pouch **1200**.

In some embodiments, the pouch **1200** may incorporate the use of dyes or other reactive chemical agents. For example, an azo dye can be used to determine whether a required sterility level has been achieved. Based on laboratory results, the time frame utilized for sterilization may be adjusted.

It is understood that the pouch **1200** and/or the system **1300** can be replicated or expanded. For example, for large facilities, multiple pouch arrays can be established to run in tandem for large number of articles to be sterilized. It is also understood that multiple pouches **1200** may be operated by a single power supply **1402**.

## REFERENCES

- [1] Y. Takeuchi, and T. Itoh, "Removal of ozone from air by activated carbon treatment", Sep. Technol., vol. 3, pp. 168-175, July 1993.
- [2] S. Lerouge, M. R. Wertheimer, and L. H. Yahia, "Plasma Sterilization: A Review of Parameters, Mechanisms, and Limitations", Plasmas and Polymers, Vol. 6, No. 3, pp. 175-187, Sep. 2001.
- [3] M. Mikumo, K. Kazama, "Plasma Sterilization Indicator", U.S. Patent 2011/0009535 A1, issued Jan. 13, 2011.

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Thus, the present invention is well adapted to carry out the objectives and attain the ends and advantages mentioned above as well as those inherent therein. While presently preferred embodiments have been described for purposes of this disclosure, numerous changes and modifications will be apparent to those of ordinary skill in the art. Such changes and modifications are encompassed within the spirit of this invention as defined by the claims.

What is claimed is:

1. A device comprising:

- a pouch having a flexible pouch wall with an inner side and an outer side, the pouch wall defining an interior of the pouch with a sealable opening and having a flame and shock resistant outer covering adjacent to a substrate, which is adjacent to an inner dielectric medium; and
- a plurality of inner electrodes embedded in the pouch wall with at least one of said plurality of inner electrodes partially exposed from the dielectric medium within the interior of the pouch, each of said plurality of inner electrodes being positionable to be directly connected with a power supply;
- two or more outer electrodes sealed from exposure to air between the dielectric medium and the substrate, each of said two or more outer electrodes being positionable to be simultaneously powered using said power supply,
- each of said outer electrodes having at least one inner electrode proximate thereto,
- wherein each of said outer electrodes only partially overlaps at least one of said at least one proximate inner electrode,
- wherein the plurality of inner electrodes generate plasma within the interior of the pouch in response to application of a voltage to both of the plurality of inner electrodes and the plurality of outer electrodes;
- wherein the plurality of inner and outer electrodes are sufficient in number and provided with sufficient volt-

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age so as to provide plasma to substantially an entire surface of a solid object within the pouch to decontaminate the object in a single operation.

2. The device of claim 1, wherein said power supply is directly connected to said plurality of electrode pairs.

3. The device of claim 1, further comprising an outlet hose passing from the inner side to the outer side of the pouch wall for evacuating gases within the pouch.

4. The device of claim 3, further comprising a filter unit connected to the outlet hose.

5. A device comprising:

- a substrate;
- a dielectric medium on a first side of the substrate;
- a plurality of electrode pairs adjacent to the dielectric medium that generate plasma on a side of the dielectric medium opposite the substrate in response to application of an electric voltage; and
- an outer covering on a second side of the substrate;

wherein one electrode of each pair of the plurality of electrode pairs is at least partially exposed on the side of the electric medium opposite the substrate, and one electrode of each pair of the plurality of electrode pairs is sealed from exposure to air between the dielectric medium and the substrate;

wherein the partially exposed electrode of each electrode pair and the sealed electrode of each electrode pair are positionable to be placed simultaneously into direct electrical contact with the applied voltage;

wherein the substrate, dielectric medium, and outer covering form a flexible pouch having an inside and an outside such that plasma is generated on the inside of the pouch and the outside of the pouch is protected from plasma exposure;

wherein the partially exposed electrode of each electrode pair and the sealed electrode of each electrode pair are positioned so as to only partially overlap each other so that a motive force urges the plasma generated by each of said electrode pair toward the inside of said pouch when said electrode pair is placed into direct electrical contact with the applied voltage;

wherein the plurality of electrode pairs are sufficient in number and provided with sufficient voltage so as to provide plasma decontamination of substantially an

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entire surface of a solid object within the pouch in a single operation without a separate mixing process.

6. The device of claim 5, wherein the pouch provides a sealable opening.

7. The device of claim 6, further comprising an outlet hose passing from the inside to the outside of the pouch.

8. The device of claim 5, further comprising a power supply electrically connected to the plurality of electrode pairs and providing a voltage thereto for the generation of plasma.

9. A method comprising:

- providing a substrate;
- providing a dielectric medium on a first side of the substrate;
- providing an outer covering on a second side of the substrate;
- providing a plurality of electrode pairs affixed to the dielectric medium with one electrode of each pair exposed on a side of the dielectric medium opposite the substrate and one electrode of each pair sealed from exposure to air by the dielectric medium and the substrate;
- forming a flexible wall from the substrate, dielectric medium, and outer covering;
- forming a pouch with a sealable open end and having the outer covering on an outside of the pouch using the flexible wall;
- inserting a solid object into the pouch and sealing the open end; and
- providing a voltage simultaneously to each of the plurality of electrode pairs to generate plasma on an interior of the pouch sufficient to provide plasma decontamination of substantially the entire surface of the solid object in a single operation without a separate mixing or stirring operation.

10. The method of claim 9, further comprising providing an evacuation hose passing from the interior of the pouch to an exterior of the pouch.

11. The method of claim 10, further comprising evacuating at least part of the air inside the pouch via the hose.

12. The method of claim 11, further comprising providing a plasma feed gas into the pouch via the hose.

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