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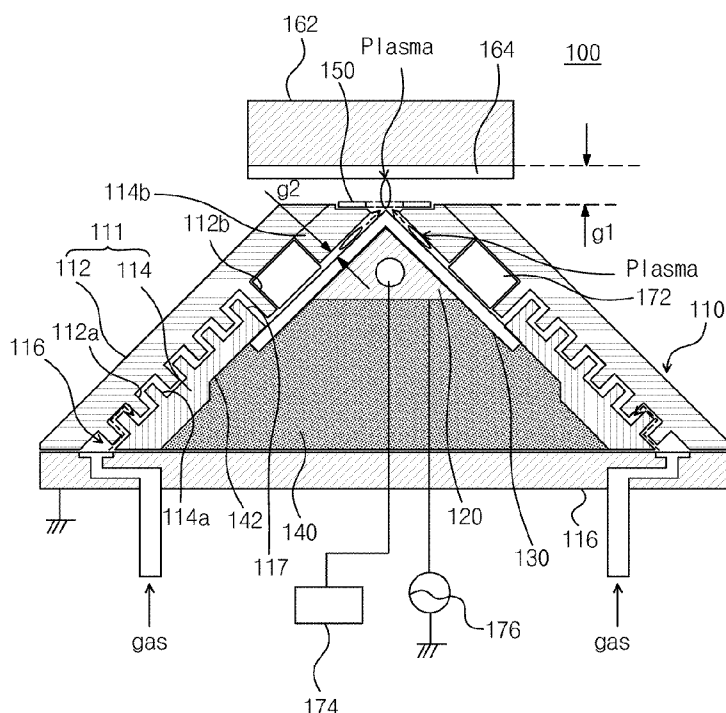
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(54) Title: LINEAR PLASMA GENERATOR FOR SELECTIVE SURFACE TREATMENT



(57) Abstract: A dielectric barrier discharge device includes: a ground electrode which includes a depression extending in a first direction and is electrically grounded; a power electrode which is buried in the depression of the ground electrode, has a portion exposed to the outside, is applied with an AC voltage, and extends in the first direction; a dielectric barrier portion which is disposed in contact with the power electrode to cover the exposed portion of the power electrode and extends in the first direction; and a mask portion which extends in the first direction, is disposed in a first area in which a target object and the exposed portion of the power electrode face each other, and spatially controls a plasma density to selectively perform a plasma treatment on the target object according to a position of the first direction.

## Description

### Title of Invention: LINEAR PLASMA GENERATOR FOR SELECTIVE SURFACE TREATMENT

#### Technical Field

- [1] The present disclosure relates to a linear plasma generator using dielectric barrier discharge (DBD) and a selective surface treatment process using the same. More specifically, the present disclosure is directed to a linear plasma generator which includes a power electrode for applying a voltage, a ground electrode, a dielectric barrier portion between the power electrode and the ground electrode, and a mask portion for selective surface treatment and may generate atmospheric plasma to perform a selective surface treatment of a film, a glass, a wafer or the like.

#### Background Art

- [2] Low-temperature plasma widely used in industry has been applied to perform a surface treatment on an object such as a semiconductor manufacturing process and a metal/ceramic thin film manufacturing process. If such low-temperature plasma is used, a surface of a low melting point material such as plastic may be prevented from melting away and surface deformation or physical property change may be prevented during a surface treatment of the low melting point material. Thus, a surface treatment of a material such as plastic or a glass is made possible.
- [3] Since atmospheric plasma may obtain low-temperature plasma at an atmospheric pressure, costs for a vacuum equipment and an equipment associated with entrance or exit of a target object may be reduced. As compared to the case where plasma processing should be performed in a vacuum state, the atmospheric plasma has an advantage to relieve a limitation in size of the target object. The atmospheric plasma is mainly generated by pulse corona discharge and dielectric barrier discharge (DBD) and means a technique to generate low-temperature plasma while maintaining a pressure of a gas from 100 Torr to an atmospheric pressure (760 Torr) or higher.
- [4] Korean Patent Registration No. 10-0760551 ("KR Pat 10-0760551") discloses a large-area plasma generating apparatus that is uniform and stable in an atmospheric state to treat a surface. The plasma generating apparatus comprises a first electrode to which rod-shaped high frequency power is applied through a matching circuit, a second electrode spaced apart from the first electrode in a length direction by a fixed distance and disposed to define a discharge area, and a dielectric barrier portion covering the first electrode for plasma discharge. However, according to the KR Pat 10-0760551, an electric field is locally established by charges accumulated on a dielectric surface covering the first electrode to cause an arc between target objects. As a

result, a defect occurs.

- [5] In a manufacturing process of a lithium ion secondary cell, an internal resistance of the cell increases when interlayer adhesive strengths between an anode and a separator and between the separator and a cathode are low. As a result, performance of the cell is significantly degraded. A surface treatment process of a separator using a corona or plasma source has been used to enhance an interlayer adhesive strength. As a thin separator film has been recently used to increase an energy density of a secondary cell, the film is damaged by an arc that occurs when a plasma treatment is performed. This causes a direct defect in a secondary cell manufacturing process. Accordingly, there is an increasing demand for process stability of an existing corona or plasma source.
- [6] Moreover, in a secondary cell manufacturing process, a process technology has been recently developed to selectively control an adhesive strength of a separator. Control of the adhesive strength may increase not only an electrical resistance characteristics between a separator and an electrode in a cell but also an aging process efficiency such that an electrolyte introduced into the cell is uniformly supplied inside the cell. In particular, the control of the adhesive strength may overcome disadvantages where an electrolyte does not fully penetrate between the separator and the electrode or a bubble is generated in an area between stacked portions of the cell.
- [7] According to an example embodiment of the present disclosure, an adhesive strength control technique using plasma may achieve effective control of an adhesive strength and allow an electrolyte to be uniformly supplied to enhance performance of a secondary cell and reduce a defect rate.
- [8] Accordingly, there is a requirement for a technique for a linear plasma generator which may suppress occurrence of an arc, secure stability of a surface treatment process through stable plasma discharge, and perform a spatially selective plasma treatment.
- [9] For the above reason, the present inventors continued to conduct a study for developing a plasma generator technology which may stably generate plasma through plasma density control in a surface treatment process area using primary discharge in a plasma source and may perform a spatially selective treatment using plasma electrode structure design and mask. By virtue of the continuous study, the present inventors completed the present invention as a dielectric barrier linear plasma generator which may perform a stable and selective plasma treatment.
- [10] [Patent Literature 1] Korean Patent Registration No. 10-0760551 (September 20, 2007)

## **Disclosure of Invention**

### **Technical Problem**

[11] Embodiments of the present disclosure provide a linear plasma generator for securing stability of plasma discharge.

[12] Embodiments of the present disclosure provide a linear plasma generator which may perform a spatially selective plasma surface treatment.

### **Solution to Problem**

[13] A dielectric barrier discharge device according to an example embodiment of the present disclosure includes: a ground electrode which includes a depression extending in a first direction and is electrically grounded; a power electrode which is buried in the depression of the ground electrode, has a portion exposed to the outside, is applied with an AC voltage, and extends in the first direction; a dielectric barrier portion which is disposed in contact with the power electrode to cover the exposed portion of the power electrode and extends in the first direction; and a mask portion which extends in the first direction, is disposed in a first area in which a target object and the exposed portion of the power electrode face each other, and spatially controls a plasma density to selectively perform a plasma treatment on the target object according to a position of the first direction.

[14] In an example embodiment, the mask portion may have a thickness of 1 millimeter or less and may include a plurality of openings arranged in the first direction.

[15] In an example embodiment, the mask portion may be formed of a conductor and may be grounded. The mask portion may be disposed to cover a top surface of the depression of the ground electrode.

[16] In an example embodiment, the power electrode may be in the form of a pillar having an edge extending in the first direction. An edge of the power electrode may be exposed to the outside.

[17] In an example embodiment, the dielectric barrier discharge device may further include: a gas distribution portion disposed in the ground electrode to supply a gas along the edge of the power electrode at opposite sides of the power electrode.

[18] In an example embodiment, the dielectric barrier discharge device may further include: a gas distribution portion disposed in the ground electrode to supply a gas to an inclined plane of the power electrode at opposite sides of the power electrode.

[19] In an example embodiment, the dielectric barrier discharge device may further include: a gas flow passage formed between the ground electrode and the dielectric barrier portion to supply a gas along an inclined plane of the power electrode at opposite sides of the power electrode. A distance between the ground electrode and the dielectric barrier portion may be 1 millimeter or less, and the gas flow passage may perform auxiliary dielectric barrier discharge to provide plasma to the first area.

[20] In an example embodiment, the dielectric barrier discharge device may further

include: an insulation block provided in the form of a triangular pillar including of a depression. The power electrode may be in the form of a triangular prism. One edge of the power electrode may be exposed to the outside. The power electrode may be disposed at the depression of the power electrode.

- [21] In an example embodiment, the ground electrode may be disposed along an inclined plane of the power electrode and an inclined plane of the insulation block. The dielectric barrier portion may be in the form of an L-shaped beam having a fixed thickness. The dielectric barrier portion may cover the inclined plane of the power electrode and a portion of the inclined plane of the insulation block.
- [22] In an example embodiment, the insulation block may further include a protrusion which extends in the first direction and protrudes to the inclined plane of the insulation block. The dielectric barrier portion may be disposed to be caught by the protrusion.
- [23] In an example embodiment, the ground electrode may include a ground electrode depression which is formed opposite to a lower side edge of the power electrode and extends in the first direction.
- [24] In an example embodiment, the dielectric barrier discharge device may further include: an arc prevention insulation block disposed at the ground electrode depression.
- [25] In an example embodiment, the ground electrode may be disposed opposite to the power electrode. The ground electrode may further include an auxiliary discharge ground electrode portion to provide an auxiliary discharge space between the ground electrode and the dielectric barrier portion.
- [26] In an example embodiment, the ground electrode may include a winding ground electrode fluid passage which is formed therein and has a slit-type section.
- [27] In an example embodiment, the mask portion may include a plurality of openings arranged in the first direction. A size of the opening may be between several hundreds of micrometers and several centimeters.
- [28] In an example embodiment, the ground electrode may further include a bottom plate ground electrode where the insulation block is disposed. The bottom plate ground electrode may include a first trench which is formed on a top surface of the bottom plate ground electrode, is disposed adjacent to a side extending in the first direction, and extends in the first direction and a second trench which is spaced apart from the first trench to be disposed adjacent to a side of an opposite direction. The first trench may include a plurality of first gas inlets, and the second trench may include a plurality of second gas inlets. The first gas inlet and the second gas inlet may be alternately disposed in the first direction.
- [29] In an example embodiment, the dielectric barrier portion may be chamfered on the edge of the power electrode such that a dielectric thickness is relatively reduced to

cause strong plasma discharge between the target objects.

- [30] In an example embodiment, the power electrode may be in the form of a cylinder. The dielectric barrier portion may be disposed to cover a circumference of the power electrode.
- [31] In an example embodiment, the exposed portion of the power electrode may have an uneven structure according to a position of the first direction.
- [32] In an example embodiment, one surface of the ground electrode facing the power electrode may have an uneven structure according to a position of the first direction.
- [33] A dielectric barrier discharge device according to an example embodiment of the present disclosure includes: a ground electrode which includes a depression extending in a first direction and is electrically grounded; a power electrode which is buried in the depression of the ground electrode, has a portion exposed to the outside, is applied with an AC voltage, and extends in the first direction; and a dielectric barrier portion which is disposed in contact with the power electrode to cover the exposed portion of the power electrode and extends in the first direction. The exposed portion of the power electrode may have an uneven structure which is disposed in a first area in which a target object and the exposed portion of the power electrode face each other, and spatially controls a plasma density to selectively perform a plasma treatment on the target object according to a position of the first direction.
- [34] In an example embodiment, the dielectric barrier discharge device may further include: a mask portion which extends in the first direction, is disposed in the first area in which the target object and the exposed portion of the power electrode face each other, and spatially controls a plasma density to selectively perform a plasma treatment on the target object according to a position of the first direction.
- [35] In an example embodiment, the mask portion may include a plurality of openings arranged in the first direction. The opening may be aligned with a protrusion of the uneven structure.
- [36] In an example embodiment, the mask portion may have a thickness of 1 millimeter or less and may include a plurality of openings arranged in the first direction.
- [37] In an example embodiment, the mask portion may be formed of a conductor and is grounded. The mask portion may be disposed to cover a top surface of the bend portion of the ground electrode.
- [38] In an example embodiment, the power electrode may be in the form of a pillar having an edge extending in the first direction. The edge of the power electrode may be exposed to the outside.
- [39] In an example embodiment, the dielectric barrier discharge device may further include: a gas discharge portion formed in the ground electrode to supply a gas along the edge of the power electrode at opposite sides of the power electrode.

- [40] In an example embodiment, the dielectric barrier discharge device may further include: a gas flow passage formed between the ground electrode and the dielectric barrier portion to supply a gas along the edge of the power electrode at opposite sides of the power electrode. A distance between the ground electrode and the dielectric barrier portion may be 1 millimeter or less, and the gas flow passage may perform auxiliary dielectric barrier discharge to provide plasma to the first area.
- [41] In an example embodiment, the dielectric barrier discharge device may further include: an insulation block provided in the form of a truncated triangular prism. The power electrode may be in the form of a triangular prism. One edge of the power electrode may be exposed to the outside. The power electrode may be disposed at a truncated portion of the insulation block.
- [42] In an example embodiment, the ground electrode may be disposed along an inclined plane of the power electrode and an inclined plane of the insulation block. The dielectric barrier portion may be in the form of an L-shaped beam having a fixed thickness. The dielectric barrier portion may cover the inclined plane of the power electrode and a portion of the inclined plane of the insulation block.
- [43] In an example embodiment, the insulation block may further include a protrusion which extends in the first direction and protrudes to the inclined plane of the insulation block. The dielectric barrier portion may be disposed to be caught by the protrusion.
- [44] In an example embodiment, the ground electrode may include a ground electrode depression which is formed opposite to a lower side edge of the power electrode and extends in the first direction.
- [45] In an example embodiment, the dielectric barrier discharge device may further include: an arc prevention insulation block disposed at the ground electrode depression.
- [46] A dielectric barrier discharge device according to an example embodiment of the present disclosure includes: a ground electrode which includes a depression extending in a first direction and is electrically grounded; a power electrode which is buried in the depression of the ground electrode, has a portion exposed to the outside, is applied with an AC voltage, and extends in the first direction; and a dielectric barrier portion which is disposed in contact with the power electrode to cover the exposed portion of the power electrode and extends in the first direction. The ground electrode may provide an auxiliary discharge area facing an electrode power supply around the exposed portion. One surface of the ground electrode facing the electrode power supply may have an uneven structure to spatially control a plasma density in the auxiliary discharge area. Plasma may be provided from the auxiliary discharge area to selectively perform a plasma treatment in a main discharge area between the target object and the power electrode according to a position of the first direction.

- [47] In an example embodiment, the dielectric barrier discharge device may further include: a mask portion which extends in the first direction, is disposed in a main discharge area in which the target object and the exposed portion of the power electrode face each other, and spatially controls a plasma density to selectively perform a plasma treatment on the target object according to a position of the first direction.
- [48] In an example embodiment, the mask portion may include a plurality of openings arranged in the first direction. The opening may be aligned with a protrusion of the uneven structure of the ground electrode.
- [49] In an example embodiment, the mask portion may be formed of a conductor, may be grounded, may be in the form of a plate having a thickness of 1 millimeter or less, and may include a plurality of openings arranged in the first direction.
- [50] In an example embodiment, the mask portion may be formed of a conductor and is grounded. The mask portion may be disposed to cover a top surface of the depression of the ground electrode.
- [51] In an example embodiment, the power electrode may be in the form of a pillar having an edge extending in the first direction. The edge of the power electrode may be exposed to the outside.
- [52] In an example embodiment, the dielectric barrier discharge device may further include: a gas distribution unit formed in the ground electrode to supply a gas along the edge of the power electrode at opposite sides of the power electrode.
- [53] In an example embodiment, the dielectric barrier discharge device may further include: a gas flow passage formed between the ground electrode and the dielectric barrier portion to supply a gas along the edge of the power electrode at opposite sides of the power electrode. A distance between the ground electrode and the dielectric barrier portion may be 1 millimeter or less. The gas flow passage may perform auxiliary dielectric barrier discharge to provide plasma to the main discharge area.
- [54] In an example embodiment, the dielectric barrier discharge device may further include: an insulation block provided in the form of a truncated triangular prism. The power electrode may be in the form of a triangular prism. One edge of the power electrode may be exposed to the outside. The power electrode may be disposed at a truncated portion of the insulation block.
- [55] In an example embodiment, the ground electrode may be disposed along an inclined plane of the power electrode and an inclined plane of the insulation block. The dielectric barrier portion may be in the form of an L-shaped beam having a fixed thickness. The dielectric barrier portion may cover the inclined plane of the power electrode and a portion of the inclined plane of the insulation block.
- [56] In an example embodiment, the insulation block may further include a protrusion which extends in the first direction and protrudes to the inclined plane of the insulation



block. The dielectric barrier portion may be disposed to be caught by the protrusion.

[57] In an example embodiment, the ground electrode may include a ground electrode depression which is formed opposite to a lower side edge of the power electrode and extends in the first direction.

[58] In an example embodiment, the dielectric barrier discharge device may further include: an arc prevention insulation block disposed at the ground electrode depression.

[59] A dielectric barrier discharge device according to an example embodiment of the present disclosure includes: a ground electrode which includes a depression extending in a first direction and is electrically grounded; a power electrode which is buried in the depression, has a portion exposed to the outside, is applied with an AC voltage, and extends in the first direction; and a dielectric barrier portion which is disposed in contact with the power electrode to cover the exposed portion of the power electrode, and extends in the first direction. Main discharge plasma may be generated in a first area, which extends in the first direction and in which a target object and the exposed portion of the power electrode face each other, to treat the target object. Auxiliary discharge plasma may be generated in a second area facing the first area between the ground electrode and the power electrode and may supply a gas of the second area to the first area to stably generate the main discharge plasma.

[60] In an example embodiment, the dielectric barrier discharge device may further include: a mask portion which extends in the first direction, is disposed in a first area in which the target object and the exposed portion of the power electrode face each other, and spatially controls a plasma density to selectively perform a plasma treatment on the target object according to a position of the first direction.

[61] In an example embodiment, the mask portion may have a thickness of 1 millimeter or less and may include a plurality of openings arranged in the first direction.

[62] In an example embodiment, the mask portion may be formed of a conductor and is grounded. The mask portion may be disposed to cover a top surface of the depression of the ground electrode.

[63] In an example embodiment, the power electrode may be in the form of a pillar having an edge extending in the first direction. The edge of the power electrode may be exposed to the outside.

[64] In an example embodiment, the dielectric barrier discharge device may further include: a gas distribution portion formed in the ground electrode to supply a gas along the edge of the power electrode at opposite sides of the power electrode.

[65] In an example embodiment, the dielectric barrier discharge device may further include: a gas flow passage formed between the ground electrode and the dielectric barrier portion to supply a gas along the edge of the power electrode at opposite sides

of the power electrode. A distance between the ground electrode and the dielectric barrier portion may be 1 millimeter or less. The gas flow passage may perform auxiliary dielectric barrier discharge to provide plasma to the first area.

[66] In an example embodiment, the dielectric barrier discharge device may further include: an insulation block provided in the form of a truncated triangular prism. The power electrode may be in the form of a triangular prism. One edge of the power electrode may be exposed to the outside. The power electrode may be disposed at a truncated portion of the insulation block.

[67] In an example embodiment, the ground electrode may be disposed along an inclined plane of the power electrode and an inclined plane of the insulation block. The dielectric barrier portion may be in the form of an L-shaped beam having a fixed thickness. The dielectric barrier portion may cover the inclined plane of the power electrode and a portion of the inclined plane of the insulation block.

[68] In an example embodiment, the dielectric barrier discharge device may further include: a protrusion which extends in the first direction and protrudes to the inclined plane of the insulation block. The dielectric barrier portion may be disposed to be caught by the protrusion.

[69] In an example embodiment, the dielectric barrier discharge device may further include: a ground electrode depression which is formed opposite to a lower side edge of the power electrode and extends in the first direction.

[70] In an example embodiment, the dielectric barrier discharge device may further include: an arc prevention insulation block disposed at the ground electrode depression.

[71] A separator film plasma processing device of a secondary cell according to an example embodiment of the present disclosure includes: a ground electrode which includes a depression extending in a first direction and is electrically grounded; a power electrode which is buried in the depression of the ground electrode, has a portion exposed to the outside, is applied with an AC voltage, and extends in the first direction; a dielectric barrier portion which is disposed in contact with the power electrodes to cover the exposed portion of the power electrode and extends in the first direction; and a mask portion which is disposed in a first area in which a separator film of a secondary cell extending in the first direction and the exposed portion of the power electrode face each other and spatially controls a plasma density to selectively perform a plasma treatment on the target object according to a position of the first direction.

[72] An atmospheric dielectric discharge plasma processing method according to an example embodiment of the present disclosure includes: providing transfer means which transfers a target object and is electrically grounded; transferring the target

object through the transfer means under an atmospheric pressure; supplying AC power to a power electrode which is buried in the ground electrode and has an exposed portion; and performing a spatially selective plasma treatment on the target object by disposing a dielectric discharge portion to cover the exposed portion of the power electrode and disposing a mask on the dielectric discharge portion.

[73] In an example embodiment, the atmospheric dielectric discharge plasma processing method may further include: generating auxiliary dielectric discharge between the ground electrode and the exposed portion of the power electrode.

[74] In an example embodiment, the atmospheric dielectric discharge plasma processing method may further include: supplying a process gas to the exposed portion of the power electrode via the ground electrode. The plasma may hydrophilically treat the target object. The process gas includes at least one of oxygen, nitrogen, hydrogen, and argon.

[75] In an example embodiment, the target object may be a separator film of a secondary cell.

### **Advantageous Effects of Invention**

[76] As described above, according to an example embodiment of the present disclosure, a plasma surface treatment is performed through dielectric barrier discharge. An arc may be prevented from occurring by supplying a gas ionized through auxiliary plasma discharge to a plasma treatment area and forming a spatially uniform fluid flow. Thus, a stable and direct plasma surface treatment process may be performed and mass-production reliability of a device may be achieved. As a result, it is possible to provide a dielectric barrier plasma generator which has more improved stability of a plasma surface treatment process than prior arts.

[77] According to an example embodiment of the present disclosure, a spatially selective plasma treatment process may be performed using at least one of a mask portion, a patterned ground electrode, and a patterned power electrode. Thus, the application range of a plasma surface treatment process may increase and ultimate product performance may be enhanced. As a result, it is possible to provide a dielectric barrier plasma generator which may improve performance of a surface treatment process and performance of an applied product as compared to prior arts.

[78] According to an example embodiment of the present disclosure, a linear plasma generator using direct dielectric barrier discharge is provided. The linear plasma generator may successively treat line-type large-area substrates or films. In the linear plasma generator, a ground electrode for trapping charges stored in a dielectric barrier surface is in contact with the dielectric barrier surface. As a result, an arc may not be caused by the surface-stored charges and a stable surface treatment process may be

performed.

### **Brief Description of Drawings**

- [79] The present disclosure will become more apparent in view of the attached drawings and accompanying detailed description. The embodiments depicted therein are provided by way of example, not by way of limitation, wherein like reference numerals refer to the same or similar elements. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating aspects of the present disclosure.
- [80] FIG. 1 is a conceptual diagram of a dielectric discharge plasma treatment apparatus according to an example embodiment of the present disclosure.
- [81] FIG. 2A is a cross-sectional view of a dielectric barrier discharge device according to an example embodiment of the present disclosure.
- [82] FIG. 2B is a top plan view of the dielectric barrier discharge device in FIG. 2A.
- [83] FIG. 3A is a perspective view of a dielectric barrier discharge device according to another example embodiment of the present disclosure.
- [84] FIG. 3B is a cross-sectional view taken along the line A-A' in FIG. 3A.
- [85] FIG. 3C is a cross-sectional view taken along the line B-B' in FIG. 3A.
- [86] FIG. 3D is a perspective view of a dielectric barrier portion and the insulation block of the dielectric barrier discharge device in FIG. 3A.
- [87] FIG. 3E is a perspective view of a power electrode of the dielectric barrier discharge device in FIG. 3A.
- [88] FIG. 3F is a perspective view of the insulation block of the dielectric barrier discharge device in FIG. 3A.
- [89] FIG. 3G is a perspective view of a ground electrode of the dielectric barrier discharge device in FIG. 3A.
- [90] FIG. 3H is a top plan view of a bottom plate of the dielectric barrier discharge device in FIG. 3A.
- [91] FIG. 4A shows a test result of a dielectric barrier discharge plasma device including a mask portion according to an example embodiment of the present invention.
- [92] FIG. 4B is an enlarged view of FIG. 4A.
- [93] FIG. 5 shows a two-dimensional simulation result indicating the magnitude of an electric field which varies depending on a material of a mask of a dielectric barrier plasma discharge device according to an example embodiment of the present disclosure.
- [94] FIG. 6 is a graph indicating an electric field cut along a mask portion in the result of FIG. 5.
- [95] FIG. 7A is a cross-sectional view of a dielectric barrier discharge device according to another example embodiment of the present disclosure.

- [96] FIG. 7B is a perspective view of a chamfered dielectric barrier portion in FIG. 7A.
- [97] FIG. 8A is a perspective view of a dielectric barrier discharge device according to another example embodiment of the present disclosure.
- [98] FIG. 8B is a cross-sectional view taken vertically to a length direction of FIG. 8A.
- [99] FIG. 8C is a cross-sectional view taken in the length direction of FIG. 8A.
- [100] FIG. 9A is a perspective view of a ground electrode of a dielectric barrier discharge device according to another example embodiment of the present invention.
- [101] FIG. 9B is a cross-sectional view at one position vertically to a length direction of the dielectric barrier discharge device in FIG. 9A.
- [102] FIG. 9C is a cross-sectional view another position vertically to the length direction of the dielectric barrier discharge device in FIG. 9A.
- [103] FIG. 10A is a cross-sectional view of a dielectric barrier discharge device according to another example embodiment of the present disclosure.
- [104] FIG. 10B is a top plan view of the dielectric barrier discharge device in FIG. 10A.

### **Mode for the Invention**

- [105] A dielectric barrier discharge device according to an example embodiment of the present disclosure provides a linear plasma generator using dielectric barrier discharge. In dielectric barrier plasma discharge, to prevent occurrence of an arc, primary plasma discharge is performed in an auxiliary discharge area in a plasma source and a primarily discharged gas is supplied to a main discharge area in which a plasma treatment is directly performed on a target object. Thus, it is expected that occurrence of an arc, which is a local discharge phenomenon, will be suppressed.
- [106] An example embodiment of the present disclosure provides a spatially uniform and stable linear plasma generator which may uniformly supply a gas through fluid analysis. In an atmospheric plasma discharge area, a flow rate of a discharge gas is one of the most important process factors to determine plasma discharge characteristics and stability of a plasma treatment process may be improved by generating spatially uniform plasma.
- [107] An example embodiment of the present disclosure provides a linear plasma generator which may secure stability of a process and may perform a selective plasma treatment. The linear plasma generator may include a power electrode to which a high voltage is applied, a ground electrode, a dielectric barrier portion between the power electrode and the ground electrode, and a mask for a selective surface treatment. In addition, the linear plasma generator may include a power electrode having an uneven structure making a selective surface treatment possible and an uneven-structured ground electrode.
- [108] Example embodiments will now be described more fully with reference to the ac-

comparing drawings, in which some example embodiments are shown. Example embodiments may, however, be embodied in many different forms and should not be construed as being limited to the embodiments set forth herein; rather, these example embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of example embodiments of inventive concepts to those of ordinary skill in the art. In the drawings, the thicknesses of layers and regions are exaggerated for clarity. Like reference characters and/or numerals in the drawings denote like elements, and thus their description may be omitted.

[109] FIG. 1 is a conceptual diagram of a dielectric discharge plasma treatment apparatus according to an example embodiment of the present disclosure.

[110] Referring to FIG. 1, a dielectric barrier discharge plasma generator system 1 may include a separator film 4 wound in the form of a roll, a roller 3 to transport the separator film 4, and a plasma device 2 to hydrophilically treat the transported separator film 4. The hydrophilically treated separator film 4 may be provided in a lamination process. The plasma device 2 may generate plasma at an atmospheric pressure and may be provided in plurality.

[111] Conventionally, among electrochemical components, separators used in a battery should be electrically isolated from each other between electrodes and should be maintained between the electrodes at a higher ion conductivity than a fixed value. Accordingly, the separator used in the battery includes a chemical which has a high ion permeability and an excellent mechanical strength and is used in an electrolyte of a system, e.g., battery and a thin porous insulating material which has excellent long-term stability with respect to a solvent. In such a battery, an electric separator should be permanently elastic and should follow movement in a system, e.g., electrode pack during charging and discharging. A separator for a Ni-MH secondary cell, which is an environment-friendly cell using a soluble electrolyte, should have an alkali resistance as an alkali-soluble electrolyte is used, should have no reactivity between electrodes, and should be economical in price. In the case that a polyolefin-based polymer is applied as the separator for a Ni-MH secondary cell, it does not have an affinity to a water-soluble alkali electrolyte due to its hydrophobic property. Therefore, a separate hydrophilicity treatment should be necessarily performed to apply the polyolefin-based polymer to the Ni-MH secondary cell. An atmospheric dielectric barrier plasma treatment may be used as the hydrophilicity treatment.

[112] FIG. 2A is a cross-sectional view of a dielectric barrier discharge device according to an example embodiment of the present disclosure.

[113] FIG. 2B is a top plan view of the dielectric barrier discharge device in FIG. 2A.

[114] Referring to FIGS. 2A and 2B, a dielectric barrier discharge device 10 according to an example embodiment of the present disclosure includes a ground electrode 30, a

power electrode 20, a dielectric barrier portion 40, and a mask portion 150. The ground electrode 30 includes a depression extending in a first direction and is electrically grounded.

[115] The power electrode 20 is buried in the bend portion of the ground electrode 30, has a portion exposed to the outside, is applied with an AC voltage, and extends in the first direction. The dielectric barrier portion 40 is disposed to be in contact with the power electrode 20 to cover the exposed portion of the power electrode 20 and extends in the first direction. The dielectric barrier portion 40 is buried in the depression of the ground electrode 30. The mask portion 150 extends in the first direction and is disposed in a first area in which a target object 164 and the exposed portion of the ground electrode 30 face each other. Thus, the mask portion 150 spatially controls a plasma density to perform a selective plasma treatment on the target object 164 according to a position of the first direction.

[116] The power electrode 20 receives AC power or RF power from an AC power supply 176 to perform dielectric barrier discharge. To perform stable and high-efficiency dielectric barrier discharge, the power electrode 20 is in the form of a pillar having an edge extending in the first direction and the edge of the power electrode 20 may be exposed to the outside. Specifically, the power electrode 20 may be in the form of a triangular prism extending in the first direction. An upper edge of the triangular prism may be exposed to the outside.

[117] The dielectric barrier portion 40 may be a dielectric substance, such as a ceramic material, having a high dielectric breakdown voltage. The dielectric barrier portion 40 is disposed to cover the edge or the exposed portion of the power electrode 20 opposite to a susceptor 162. The dielectric barrier portion 40 may be disposed to cover all surfaces of the power electrode 20. The dielectric barrier portion 40 may be in the form of a triangular prism covering the power electrode 20 having the form of a triangular prism. The dielectric barrier portion 40 may be thick enough on a bottom surface of its triangular prism and may be thin on an inclined plane of its triangular prism. When a strong electric field is established between the susceptor 162 and the edge of the power electrode 20, surface charges or memory charges may be generated at the corner of the dielectric barrier portion 40. A thickness on the inclined plane of the dielectric barrier portion 40 or a distance between the ground electrode 30 and the power electrode 20 may be small enough to remove the memory charges. On the inclined plane of the dielectric barrier portion 40, the ground electrode and the power electrode may operate as a parallel plate capacitor. On a bottom surface of the triangular prism, the dielectric barrier portion 40 may be thick enough to reduce parasitic power consumption. On the bottom surface of the dielectric barrier portion 40, the ground electrode 30 and the power electrode 20 may operate as a parallel plate capacitor.

- [118] The distance between the susceptor 162 and the edge of the dielectric barrier portion 40 may be a distance which is capable of inducing dielectric barrier discharge. The edge of the power electrode 20 may collect sufficient charges and may establish an electric field required for discharge. Since an electron cannot obtain sufficient energy when the distance is less than several hundreds of micrometers, atmospheric dielectric barrier discharge cannot be generated. Since the sufficient magnitude of an electric field cannot be obtained when the distance is several centimeters, dielectric barrier discharge is not generated. Accordingly, a discharge distance for dielectric discharge may be between several hundreds of micrometers and several millimeters.
- [119] A thickness of the edge of the dielectric barrier portion 40 may be between several tens of micrometers and several millimeters to overcome a dielectric breakdown voltage.
- [120] The ground electrode 30 may include a depression or a cavity formed therein. The ground electrode 30 may be formed by combining a plurality of parts with each other. The ground electrode 30 is formed of a conductor and is electrically grounded. The depression has an opening formed on a top surface of the ground electrode 30. The depression may have the shape of a triangular prism, and the dielectric barrier portion 40 may be inserted into the depression.
- [121] A top surface of the ground electrode 30 is a plane, and the edge of the dielectric barrier portion 40 is disposed at a top surface or an opening of the depression of the ground electrode 30. A gas distribution portion 32 may be disposed inside the ground electrode 30. The gas distribution portion 32 may be formed inside the ground electrode 30 and may supply a gas along the edge of the power electrode 20 at opposite sides of the power electrode 20. The gas distribution portion 32 may be connected to a top surface of the ground electrode 30 and may be in the form of a slit or a plurality of nozzles extending in the first direction. The gas distribution portion 32 may supply a gas at opposite sides on the basis of an upper edge of the power electrode 20.
- [122] The gas distribution portion 32 provides a fluid path through which a gas flows, and the fluid passage may be formed parallel to the inclined plane of the power electrode 20 inside the ground electrode 30. The gas distribution portion 32 may be connected to a buffer space 31 disposed inside the ground electrode 30. The buffer space 31 may provide a diffusion space to spatially uniformly inject a gas. A gas is externally supplied to the buffer space 31.
- [123] The susceptor 162 is means for fixing or moving the target object 164, is formed of a conductor, and is grounded. The susceptor 162 may be a plate-shaped or cylindrical roller. The target object 164 may closely adhere to the susceptor 162. Dielectric barrier discharge is generated between the susceptor 162 and the upper edge of the power electrode 20.



- [124] When a plasma treatment is desired to be selectively performed on a specific portion such as a line pattern of the target object 164, the mask portion 150 may be disposed on the opening of the ground electrode 30.
- [125] The mask portion 150 may have a pattern having a plurality of openings and may be formed of a ceramic material or a conductor. Preferably, the mask portion 150 is formed of a conductor, is grounded, and is disposed to cover the top surface (or opening) of the bend portion of the ground electrode 30. The mask portion 150 may be in the form of a plate having a thickness of 1 millimeter or less and may have a plurality of openings arranged in the first direction. Preferably, the mask portion 150 is thin. The upper edge of the dielectric barrier portion 40 may be in substantial contact with a bottom surface of the mask portion 150. Since one area of the grounded conductive mask portion 150 and the dielectric barrier portion 40 are in contact with each other or do not provide a sufficient space, dielectric barrier discharge is not generated. In another area of the grounded conductive mask portion 150, the susceptor 162 and the upper edge of the power electrode 20 perform dielectric barrier discharge. Thus, a plasma treatment may be selectively performed according to a position of the target object 164 as dielectric barrier discharge is locally generated in the first direction.
- [126] The AC power supply 176 may have a frequency of several KHz to several hundreds of KHz and may supply the frequency of several KHz to several hundreds of KHz to the power electrode 20. A waveform of the AC power supply 176 may be a sine wave, a square wave or a sawtooth wave.
- [127] According to a modified embodiment of the present disclosure, the ground electrode 30 may be variously modified so long as it is disposed to cover the exposed portion of the power electrode 20. A dielectric barrier layer may be variously modified so long as it covers the edge of the power electrode 20.
- [128] FIG. 3A is a perspective view of a dielectric barrier discharge device according to another example embodiment of the present disclosure.
- [129] FIG. 3B is a cross-sectional view taken along the line A-A' in FIG. 3A.
- [130] FIG. 3C is a cross-sectional view taken along the line B-B' in FIG. 3A.
- [131] FIG. 3D is a perspective view of a dielectric barrier portion and the insulation block of the dielectric barrier discharge device in FIG. 3A.
- [132] FIG. 3E is a perspective view of a power electrode of the dielectric barrier discharge device in FIG. 3A.
- [133] FIG. 3F is a perspective view of the insulation block of the dielectric barrier discharge device in FIG. 3A.
- [134] FIG. 3G is a perspective view of a ground electrode of the dielectric barrier discharge device in FIG. 3A.

- [135] FIG. 3H is a top plan view of a bottom plate of the dielectric barrier discharge device in FIG. 3A.
- [136] Referring to FIGS. 3A to 3H, a dielectric barrier discharge device 100 includes a ground electrode 110, a power electrode 120, a dielectric barrier portion 130, and a mask portion 150. The ground electrode 110 includes a bend portion 110a extending in a first direction and is electrically grounded. The power electrode 120 is buried in the bend portion, has a portion 110a exposed to the outside, is supplied with an AC voltage, and extends in the first direction. The dielectric barrier portion 130 is in contact with the power electrode 120 to be disposed to cover the exposed portion 110a of the power electrode 120 and extends in the first direction. The mask portion 150 extends in the first direction and is disposed in a first area in which a target object 164 and the exposed portion 110a face each other. Thus, the mask portion 150 may spatially control a plasma density to selectively perform a plasma treatment on the target object 164 according to a position of the first direction.
- [137] The power electrode 120 may be in the form of a triangular pillar. The ground electrode 110 is disposed to face opposite side surfaces (inclined planes) of the power electrode 120. The power electrode 110 is disposed to expose an upper edge of the power electrode 120. The upper edge of the power electrode 120 and a susceptor 162 may perform main dielectric barrier discharge in a first area with the dielectric barrier portion 130 interposed therebetween. The inclined plane of the power electrode 120 and the ground electrode 110 may perform auxiliary dielectric barrier discharge in a second area with the dielectric barrier portion 130 interposed therebetween. When only the main dielectric barrier discharge is performed, memory charges may be locally generated at the upper edge to cause arc discharge. To reduce the arc discharge, plasma, electrons, an inert gas generated by the auxiliary dielectric discharge are supplied to the first area in which the main dielectric barrier discharge is performed, and thus stable discharge may be performed even at a low voltage. As a result, discharge stability is enhanced. For the dielectric barrier discharge, a vertical distance between the inclined plane of the power electrode 120 and the ground electrode 110 may be several millimeters. Specifically, a vertical distance  $g_1$  between the dielectric barrier portion 130 and the susceptor 162 on the upper edge of the power electrode 120 may be approximately 1 millimeter. Accordingly, a thickness of the mask portion 150 may be 1 millimeter or less. On the other hand, a vertical distance  $g_2$  between the dielectric barrier portion 130 and the ground electrode 110 on the inclined plane of the power electrode 120 may be approximately 1 millimeter. Due to auxiliary dielectric discharge, stable plasma is established to remove memory charges and provide seed charges required for main dielectric discharge. A gas may provide a uniform fluid flow along the side surface (inclined plane) of the dielectric barrier portion 130 in an upper

- edge direction to enhance discharge stability and cool the dielectric barrier portion 130.
- [138] The power electrode 120 may have a long hole formed therein in the first direction. A coolant may flow through the hole. The coolant may be introduced at one end of the power electrode 120 and flow along the power electrode 120 in the first direction, and then may be discharged at the other end of the power electrode 120. AC power may be supplied to a center portion of the power electrode 120.
- [139] The dielectric barrier portion 130 may be in the form of an L-shaped beam having a fixed thickness, may cover the upper edge and the inclined plane of the power electrode 120, and may cover a portion of an inclined plane of an insulation block 140. A material of the dielectric barrier portion 130 may be a ceramic or plastic-based material. According to a modified embodiment of the present disclosure, the dielectric barrier portion 130 and the insulation block 140 may be integrated into one body.
- [140] The insulation block 140 may be in the form of a triangular pillar in the first direction, and an upper edge of the triangular pillar may include a depression 147 allowing the power electrode 120 to be inserted. A material of the insulation block 140 may be a ceramic or plastic material. The dielectric barrier portion 130 may extend in the first direction to cover the inclined plane of the power electrode 120 and the inclined plane of the insulation block 140 and may extend in an inclined plane direction to cover a portion of the inclined plane of the insulation block 140.
- [141] The insulation block 140 may extend in the first direction and may include a protrusion 142 protruding on the inclined plane of the insulation block 140. The electric barrier portion 130 may be disposed to be caught by the protrusion 142. A strong electric field may be established at a lower edge of the power electrode 120, and the power electrode 120 and the ground electrode 110 may cause parasitic discharge or arc discharge at a fine gap between the power electrode 120 and the ground electrode 110. The protrusion 142 of the insulation block 140 is disposed to suppress the parasitic discharge. A path connecting the lower edge of the power electrode 120 with the ground electrode 110 may be curved by a height of the protrusion 142 to suppress the parasitic discharge.
- [142] The ground electrode 110 may be wholly in the form of a hollow truncated triangular prism. Alternatively, a slit-type opening extending in the first direction may be formed at a truncated portion of the ground electrode 110. The power electrode 120 may be buried in the ground electrode 110, and an upper edge of the power electrode 120 may be disposed below the opening of the ground electrode 110. Alternatively, the ground electrode 110 may be disposed to cover the power electrode 120 except for an exposed portion of the power electrode 120 extending in the first direction.
- [143] The upper edge of the power electrode 120 or the upper edge of the dielectric barrier portion 130 may substantially match a truncated surface of the ground electrode 110.

- [144] The ground electrode 110 may include a pair of side ground electrodes 111, a pair of auxiliary side ground electrodes 111a, and a bottom plate ground electrode 116. The side ground electrode 111 is disposed opposite to the inclined plane of the power electrode 120 and the inclined plane of the insulation block 140. The side ground electrode 111 extends in the first direction, and the auxiliary side ground electrode 111a extends in a direction perpendicular to the first direction to be disposed at opposite ends of the insulation block 140.
- [145] Gas distribution portions 112a and 114a may be formed inside the side ground electrode 111 and may supply a gas the inclined plane of the dielectric barrier portion 130 at the opposite sides of the power electrode 120. Specifically, the gas distribution portions 112a and 114a may include a first line pattern 112a and a second line pattern 114a. The side ground electrode 111 may include a top plate 112 and a bottom plate 114. One surface of the top plate may include a plurality of first line patterns 112a protruding and extending in the first direction. One surface of the bottom plate may include a plurality of second line patterns 114a protruding and extending in the first direction. The first line pattern 112a and the second line pattern 114a may be alternately arranged. A gas may pass a winding fluid passage, which is formed by the first line pattern 112a and the second line pattern 114a, through a slit-type gas inlet 116 formed on a bottom surface of the side ground electrode 111. Accordingly, the gas may receive a resistance in a diagonal direction to uniformly spread in the first direction. As a result, a gas outlet 117 of the side ground electrode 111 may discharge a gas in a direction of the dielectric barrier portion 130 and may maintain a uniform density in the first direction.
- [146] A gas flow passage may be formed between the side ground electrode 111 and the dielectric barrier portion 130 to supply a gas along the inclined plane of the dielectric barrier portion 130 at the opposite sides of the dielectric barrier portion 130. Of the gas flow passage, an area in which the ground electrode 110 and the power electrode 120 face each other may provide an auxiliary discharge space (second area). The auxiliary discharge space may generate auxiliary dielectric barrier plasma.
- [147] The side ground electrode 111 may be formed opposite to a lower side edge of the power electrode 120 and may include a ground electrode depression 112b extending in the first direction. The ground electrode depression 112b may provide a gas buffer space when it is not filled with a dielectric material.
- [148] The ground electrode depression 112b may be filled by an arc prevention insulation block 172. The arc prevention insulation block 172 may be in the form of a square pillar of a ceramic or plastic material.
- [149] A distance between the side ground electrode 111 and the dielectric barrier portion 130 may be 1 millimeter or less, and the gas flow passage may perform auxiliary di-

electric barrier discharge to provide plasma to the first area.

- [150] A gas discharged from the gas outlet 117 of the gas distribution portion may be supplied to the auxiliary discharge space (second area) after passing a space between the arc prevention insulation block 172 and the dielectric barrier portion 130. The arc prevention insulation block 172 may sufficiently increase a distance between the power electrode 120 and the ground electrode 110 to suppress dielectric barrier discharge and arc discharge.
- [151] The side ground electrode 111 may include an auxiliary discharge ground electrode portion 114b to provide an auxiliary discharge space between the ground electrode 110 and the dielectric barrier portion 130. The auxiliary discharge ground electrode portion 114b may be a metal alloy that is resistant to thermal deformation. A vertical distance g2 between the auxiliary discharge ground electrode portion 114b and the dielectric barrier portion 130 may be several millimeters.
- [152] If the vertical distance g2 is too long, auxiliary dielectric barrier discharge is not generated. Accordingly, only main dielectric barrier discharge is generated between the susceptor 162 and the upper edge of the power electrode 120 in the first area, and thus discharge stability may be deteriorated due to arc discharge.
- [153] The bottom plate ground electrode 116 is combined with a bottom surface of the side ground electrode 111 and supports a bottom surface of the insulation block 140. The bottom plate ground electrode 116 may have a first trench 215 and a second trench 225. The first trench 215 is formed on a top surface of the bottom plate ground electrode 116, is disposed adjacent to a side extending in the first direction, and extends in the first direction. The second trench 225 is spaced apart from the first trench 215 to be disposed adjacent to a side of opposite direction. A first gas outlet 214 is connected to a fluid passage formed in the bottom plate ground electrode 116 through a gas inlet 216 formed around a bottom surface of the first trench 215. A second gas outlet 223 is connected to the fluid passage formed in the bottom plate ground electrode 116 through a gas inlet 222 formed around a bottom surface of the second trench 225.
- [154] The first trench 215 may include a plurality of first gas outlets 214, the second trench 225 may include a plurality of second gas outlets 223, and the first gas outlets 214 and the second gas outlets 223 may be alternately arranged. The first trench 215 is connected to a gas inlet 116 of one side ground electrode, and the second trench 225 is connected to a gas inlet 116 of the other side ground electrode.
- [155] A coolant pipe through-hole 211 and a power line through-hole 212 may be formed in the bottom plate ground electrode 116. A pipe in which a coolant flows may move through the coolant pipe through-hole 211, and a power line for supplying AC power moves through the power line through-hole 212.

- [156] The mask portion 150 may be disposed on a truncated surface of the ground electrode 110 to perform a selective treatment on the target object 164. The mask portion 150 may include a plurality of openings 151 or opening patterns arranged in the first direction. A size of the opening may be between several hundreds of micrometers and several centimeters. The mask portion 150 is in the form of a plate having a thickness of 1 millimeter or less and includes a plurality of openings arranged in the first direction. The mask portion 150 may be a ceramic material, a metal or a metal-alloy.
- [157] Preferably, the mask portion 150 may be a conductor, may be grounded, and may be disposed to cover a top surface of the depression 110a of the ground electrode 110. That is, the mask portion 150 may be aligned with an opening of the truncated surface of the ground electrode 110. The mask portion 150 may not locally generate main dielectric barrier discharge in the first direction. In a closed area of the mask portion 150, the main dielectric barrier discharge is not generated. In an opened area of the mask portion 150, the main dielectric barrier discharge is generated. Accordingly, the target object 164 may have a treated area and a non-treated area in the first direction.
- [158] According to a modified embodiment of the present disclosure, the mask portion 150 may not be in contact with the ground electrode 110 and may be disposed adjacent to a lower portion of the target object 164. In this case, the mask portion 150 may various two-dimensional patterns. On the other hand, when the target object 164 and the mask portion 150 are fixed, a linear dielectric barrier plasma device may form a two-dimensional pattern on the target object 164 while moving.
- [159] According to a modified embodiment of the present disclosure, the mask portion 150 may not be in contact with the ground electrode 110 and may be disposed below the target object 164. In this case, the mask portion 150 may have various two-dimensional patterns. In the case that the target object 164 and the mask portion 150 move at the same time, the linear dielectric barrier plasma device may be fixed. If the target object 164 and the mask portion 150 move at the same time, a two-dimensional pattern may be formed on the target object 164.
- [160] Continuing to refer to FIGS. 3A to 3H, a separator film plasma treatment apparatus 100 of a secondary cell includes a ground electrode 110 which includes a depression extending in a first direction and is electrically grounded, a power electrode 120 which is buried in the depression of the ground electrode 110, has a portion exposed to the outside, is applied with an AC voltage, and extends in the first direction, a dielectric barrier portion 130 which is disposed in contact with the power electrode 120 to cover the exposed portion of the power electrode 120 and extends in the first direction, and a mask portion 150 which is disposed in a first area in which a separator film of the secondary cell extending in the first direction and the exposed portion of the power

electrode 120 face each other and spatially controls a plasma density to selectively perform a plasma treatment on a target object 164 according to a position of the first direction.

- [161] The target object 164 may be a separator film of a secondary cell. The target object 164 may be disposed at a susceptor (or roller) to be movable. Main dielectric barrier discharge is generated in the first area, and the first area includes a mask portion where a plasma density is spatially modulated in the first area. Thus, the separator film may have line-type hydrophilicity-treated areas extending parallel to each other.
- [162] Still referring to FIGS. 3A to 3H, an atmospheric dielectric discharge plasma treatment method includes transferring the target object 164 and providing electrically grounded transfer means 162, transferring the target object 164 through the transfer means 162 under an atmospheric pressure, supplying AC power to the power electrode 120 which is buried in the ground electrode 110 and has an exposed portion, and disposing a dielectric discharge portion 130 to cover the exposed portion of the power electrode 120 and disposing the mask portion 150 on the dielectric discharge portion 130 to perform a spatially selective plasma treatment on the target object 164.
- [163] A process gas may be supplied to the exposed portion of the power electrode 120 through the ground electrode 110. The plasma may hydrophilically treat the target object 164, and the process gas may include at least one of oxygen, nitrogen, hydrogen, and argon. The target object 164 may be a separator film of a secondary cell.
- [164] If the power electrode is in the form of a triangular pillar, auxiliary dielectric discharge may be generated between the ground electrode 110 and the exposed portion of the power electrode 120 (or an inclined plane of the power electrode 120). To this end, a second area is formed between the ground electrode 110 and the dielectric barrier portion 130 and the process gas may be supplied through the second area.
- [165] FIG. 4A shows a test result of a dielectric barrier discharge plasma device including a mask portion according to an example embodiment of the present invention.
- [166] FIG. 4B is an enlarged view of FIG. 4A. In FIGS. 4A and 4B, the same components or parts as those shown in FIG. 3 are designated with the same numerals and their explanations will be omitted.
- [167] Referring to FIGS. 4A and 4B, the target object 164 in FIG. 2 is removed and an ultraviolet (UV) sensitive film is disposed. The UV sensitive film is used to indirectly measure a plasma density.
- [168] In Embodiment 1, a pattern period of a mask portion is 4 millimeters and a size of an opening is 2 millimeters (red). In Embodiment 2, a pattern period of a mask pattern is 4 millimeters and a size of an opening is 4 millimeters (blue). A comparative example is a result measured without a mask.
- [169] According to a test result, a selective plasma treatment is accurately performed

according to a pattern of the mask portion.

[170] FIG. 5 shows a two-dimensional simulation result indicating the magnitude of an electric field which varies depending on a material of a mask of a dielectric barrier plasma discharge device according to an example embodiment of the present disclosure.

[171] FIG. 6 is a graph indicating an electric field cut along a mask portion in the result of FIG. 5.

[172] Referring to FIGS. 5 and 6, a material of a mask portion may be a metal mask or a ceramic mask. A spatial distribution of an electric field is displayed according to a material of each material

[173] When the mask portion is not used, position-dependent magnitude of the electric field is constant. However, when the metal mask is used, the magnitude of the electric field is 1 in an opened area and 0.6 in a closed area. Thus, the magnitude difference of the electric field may provide ON/OFF of dielectric barrier discharge.

[174] When the ceramic mask is used, the magnitude of the electric field is 0.9 in the opened area and 0.83 in the closed area. Thus, the magnitude difference of the electric field may minutely provide ON/OFF of the dielectric barrier discharge.

[175] FIG. 7A is a cross-sectional view of a dielectric barrier discharge device according to another example embodiment of the present disclosure.

[176] FIG. 7B is a perspective view of a chamfered dielectric barrier portion in FIG. 7A. In FIGS. 7A and 7B, the same components or parts as those shown in FIG. 3 are designated with the same numerals and their explanations will be omitted.

[177] Referring to FIGS. 7A and 7B, a dielectric barrier discharge device 100a may include a ground electrode 100, a power electrode 120, a dielectric barrier portion 130, and an insulation block 140.

[178] The ground electrode 110 includes a depression extending in a first direction and is electrically grounded. The power electrode 120 is buried in the depression, has a portion exposed to the outside, is applied with an AC voltage, and extends in the first direction. Main discharge plasma is generated in the first direction and is generated in a first area (main discharge area), in which a target object and the exposed portion of the power electrode 120 face each other, to treat the target object. Auxiliary discharge plasma is generated in a second area (auxiliary discharge area) facing the first area between the ground electrode and the power electrode and supplies a gas of the second area to the first area to stably generate the main discharge plasma.

[179] The power electrode may be in the form of a pillar having an edge extending in the first direction, and the edge of the power electrode 120 may be exposed to the outside. Specifically, the power electrode 130 may be in the form of a triangular prism.

[180] The dielectric barrier portion 130 may be in the form of an L-shaped beam having a



fixed thickness and may cover an inclined plane of the power electrode 120 and a portion of an inclined plane of the insulation block 140. An upper edge of the dielectric barrier portion 130 may be chamfered. Thus, a distance between the upper edge of the power electrode 120 and a susceptor 162 may be adjusted. As a result, the magnitude of the main discharge plasma may be adjusted.

[181] The ground electrode 110 may be disposed along the inclined plane of the power electrode 120 and the insulation block 140.

[182] A gas flow passage may be formed between the ground electrode 110 and the dielectric barrier portion 130, and a gas may be supplied along the edge of the power electrode 120 at opposite sides of the power electrode 120. In the gas flow passage, a distance between the ground electrode 110 and the dielectric barrier portion 130 may be 1 millimeter or less. The gas flow passage may perform auxiliary dielectric barrier discharge to provide plasma to the first area.

[183] The mask portion 150 may extend in the first direction, may be disposed in the first area in which the target object and the exposed portion of the power electrode 120 face each other, and may spatially control a plasma density to selectively perform a plasma treatment on the target object according to a position of the first direction. The mask portion 150 may be formed of a conductor, may be grounded, and may be disposed to cover a top surface of the depression of the ground electrode 110. The mask portion 150 may have a thickness of 1 millimeter or less and may include a plurality of openings arranged in the first direction.

[184] FIG. 8A is a perspective view of a dielectric barrier discharge device according to another example embodiment of the present disclosure.

[185] FIG. 8B is a cross-sectional view taken vertically to a length direction of FIG. 8A.

[186] FIG. 8C is a cross-sectional view taken in the length direction of FIG. 8A. In FIGS. 8A to 8C, the same components or parts as those shown in FIG. 3 are designated with the same numerals and their explanations will be omitted.

[187] Referring to FIGS. 8A to 8C, a dielectric barrier discharge device 100b includes a ground electrode 110, a power electrode 120, and a dielectric barrier portion 130.

[188] The ground electrode 110 includes a depression extending in a first direction and is electrically grounded. The power electrode 120 is buried in the depression of the ground electrode 110, has a portion exposed to the outside, is applied with an AC voltage, and extends in the first direction. The dielectric barrier portion 130 is disposed in contact with the power electrode 120 to cover the exposed portion of the power electrode 120 and extends in the first direction. The exposed portion of the power electrode 120 has uneven structures 120a and 120b that are disposed in a first area, in which a target object and the exposed portion of the power electrode 120 face each other, and spatially control a plasma density to selective perform a plasma treatment on

the target object according to a position of the first direction.

- [189] To selectively treat the target object, a discharge distance of dielectric barrier discharge (a distance between a top surface of the power electrode 120 and a susceptor 162) is made variable depending on a position. Specifically, a distance between an upper edge of the power electrode 120 and the susceptor 162 may vary depending on the first direction. The power electrode 120 may be in the form of a triangular pillar, and an upper edge of the triangular pillar may be periodically depressed to include a protrusion 120a and a depression 120b. A distance from the depression 120b to the susceptor 162 may be set such that dielectric barrier discharge is not efficiently generated. Specifically, a depth of the depression 120b may be several millimeters or more. The dielectric barrier discharge is generated at the protrusion 120a, while the dielectric barrier discharge is not generated at the depression 120b. Thus, the protrusion 120a may selectively perform a plasma treatment on the target object in the first direction.
- [190] To increase a selectivity of the plasma treatment, the mask portion 150 aligned with the uneven structures 120a and 120b of the power electrode 120 may be disposed at an opening of a depression of the ground electrode 110. The mask portion 150 may be formed of a conductor, may be grounded, and may be disposed to cover a top surface of the depression of the ground electrode 110. The mask portion 150 may extend in the first direction, may be disposed in a first area in which the target object and the exposed portion of the power electrode 120 face each other, and may spatially control a plasma density to selectively perform a plasma treatment on the target object according to a position of the first direction. The mask portion 150 may include a plurality of openings arranged in the first direction, and the opening of the mask portion 150 may be aligned with the protrusion 120a of the uneven structures 120a and 120b.
- [191] The dielectric barrier portion 130 is disposed to cover an upper edge of the power electrode 120. The dielectric barrier portion 130 may be transformed to fill the depression 120a of the power electrode 120.
- [192] According to a modified embodiment of the present disclosure, the ground electrode 110 may provide an auxiliary discharge area facing an electrode power supply around the exposed portion of the power electrode 120, and one surface of the ground electrode 110 facing the electrode power supply may include an uneven structure (not shown) to spatially control a plasma density in the auxiliary discharge area. Plasma may be provided from the auxiliary discharge area to selectively perform a plasma treatment on a target object in a main discharge area between the target object and the power electrode according to a position of the first direction.
- [193] FIG. 9A is a perspective view of a ground electrode of a dielectric barrier discharge device according to another example embodiment of the present invention.

- [194] FIG. 9B is a cross-sectional view at one position vertically to a length direction of the dielectric barrier discharge device in FIG. 9A.
- [195] FIG. 9C is a cross-sectional view another position vertically to the length direction of the dielectric barrier discharge device in FIG. 9A. In FIGS. 9A to 9C, the same components or parts as those shown in FIG. 3 are designated with the same numerals and their explanations will be omitted.
- [196] Referring to FIGS. 9A to 9C, a dielectric barrier discharge device 100c includes a ground electrode 110, a power electrode 120, and a dielectric barrier portion 130.
- [197] The ground electrode 110 includes a depression extending in a first direction and is electrically grounded. The power electrode 120 is buried in the depression of the ground electrode 110, has a portion exposed to the outside, is applied with an AC voltage, and extends in the first direction. The dielectric barrier portion 130 is disposed in contact with the power electrode 120 to cover the exposed portion of the power electrode 120 and extends in the first direction. The ground electrode 110 provides an auxiliary discharge area facing an electrode power supply around the exposed portion of the power electrode 120, and one surface of the ground electrode 110 facing the electrode power supply includes an uneven structure 119 to spatially control a plasma density in the auxiliary discharge area. Plasma is provided from the auxiliary discharge area to selectively perform a plasma treatment on a target object in a main charge area between the target object and the power electrode 120 according to a position of the first direction.
- [198] The ground electrode 110 may include a pair of side ground electrodes 111, a pair of auxiliary side ground electrodes 111a, and a bottom plate ground electrode 116. The side ground electrode 111 is disposed opposite to an inclined plane of the power electrode 120 and an inclined plane of an insulation block 140. The side ground electrode 111 extends in the first direction, and the auxiliary side ground electrode 111a extends perpendicularly to the first direction to be disposed at opposite ends of the insulation block 140.
- [199] Gas distribution portions 112a and 114a may be formed in the side ground electrode 111 to supply a gas to the inclined plane of the dielectric barrier portion 130 at opposite sides of the power electrode 120. Specifically, the gas distribution portions 112a and 114a may include a first line pattern 112a and a second line pattern 114a. The side ground electrode 111 may include a top plate 112 and a bottom plate 114. One surface of the top plate 112 may include a plurality of first line patterns 112a which extend in the first direction and protrude. One surface of the bottom plate 114 may include a plurality of second line patterns 114a which extend in the first direction and protrude. The first line patterns 112a and the second line patterns 114a may be alternately arranged. A gas may pass a winding fluid passage formed by the first line

patterns 112a and the second line patterns 114a through a slit-type gas inlet 116 formed on a bottom surface of the side ground electrode 111. Thus, the gas may receive a resistance in a diagonal direction to uniformly spread in the first direction. As a result, a gas outlet 117 of the side ground electrode 111 may discharge a gas in a direction of the dielectric barrier portion 130 and may maintain a uniform density in the first direction.

- [200] A gas flow passage may be formed between the side ground electrode 111 and the dielectric barrier portion 130 to supply a gas along the inclined portion of the dielectric barrier portion 130 at opposite sides of the dielectric barrier portion 130. Of the gas flow passage, an area in which the ground electrode 110 and the power electrode 120 face each other may be provided in an auxiliary discharge space (second area). The auxiliary discharge space may generate auxiliary dielectric barrier plasma.
- [201] The side ground electrode 111 may be formed opposite to a lower side edge of the power electrode 120 and may include a ground electrode depression 112b extending in the first direction. The ground electrode depression 112b may provide a gas buffer space when it is not filled with a dielectric material.
- [202] The ground electrode depression 112b may be filled with an arc prevention insulation block 172. The arc prevention insulation block 172 may be in the form of a square pillar which extends in the first direction and is formed of a ceramic or plastic material.
- [203] A distance between the side ground electrode 111 and the dielectric barrier portion 130 is 1 millimeter or less, and the gas flow passage performs auxiliary dielectric barrier discharge to provide plasma to the first area.
- [204] A gas discharge from the gas outlet 117 of the gas distribution portion may be provided to the auxiliary discharge space (second area) after passing a space between the arc prevention insulation block 172 and the dielectric barrier portion 130. The arc prevention insulation block 172 may sufficiently increase a distance between the power electrode 120 and the ground electrode 110 to suppress dielectric barrier discharge and arc discharge.
- [205] The side ground electrode 111 may include an auxiliary discharge ground electrode portion 114b to provide an auxiliary discharge space between the ground electrode 110 and the dielectric barrier portion 130. The auxiliary discharge ground electrode portion 114b may provide the auxiliary discharge space (second area). The auxiliary discharge ground electrode portion 114b may be a metal alloy that is resistant to thermal deformation. A vertical distance g2 between the auxiliary discharge ground electrode portion 114b and the dielectric barrier portion 130 may be several millimeters.
- [206] The auxiliary discharge ground electrode portion 114b may have an uneven structure 119 formed on its surface and may selectively generate auxiliary dielectric barrier discharge. Due to the uneven structure 119, a protrusion of the auxiliary discharge

ground electrode portion 114b and the dielectric barrier portion 130 may have a first distance such that the auxiliary dielectric discharge is generated. In addition, a depression of the auxiliary discharge ground electrode portion 114b and the dielectric barrier portion 130 may have a second distance such that the auxiliary dielectric discharge is not generated.

[207] If the vertical distance g2 is too longer, the auxiliary dielectric barrier discharge is not generated. Accordingly, since there is no charge provided by the auxiliary dielectric discharge, main dielectric barrier discharge may be weakly generated or may not be generated between the susceptor 162 and an upper edge of the power electrode 120 in the first area. As a result, the target object may be selectively treated according to a position.

[208] To expedite a selective treatment, the mask portion 150 may extend in the first direction, may be disposed in a main discharge area in which the target object and the exposed portion of the power electrode 120 face each other, and may spatially control a plasma density to selectively perform a plasma treatment on the target object according to a position of the first direction.

[209] The mask portion 150 may include a plurality of openings arranged in the first direction, and the opening of the mask portion 150 may be aligned with a protrusion of the uneven structure of the ground electrode 110. The mask portion 150 may be formed of a conductor, may be grounded, may be in the form of a plate having a thickness of 1 millimeter or less, and may include a plurality of openings arranged in the first direction. The protrusion of the ground electrode 110 may be aligned with the opening of the mask portion 150, and the depression of the ground electrode 110 may be aligned with a closed area of the mask portion 150.

[210] According to a modified embodiment of the present disclosure, to expedite a selective treatment, the exposed portion of the power electrode 120 may have an uneven structure which is disposed in a first area in which the target object and the exposed portion of the power electrode face each other and spatially controls a plasma density to selectively perform a plasma treatment on the target object according to a position of the first direction.

[211] FIG. 10A is a cross-sectional view of a dielectric barrier discharge device according to another example embodiment of the present disclosure.

[212] FIG. 10B is a top plan view of the dielectric barrier discharge device in FIG. 10A. In FIGS. 10A and 10B, the same components or parts as those shown in FIG. 3 are designated with the same numerals and their explanations will be omitted.

[213] Referring to FIGS. 10A and 10B, a dielectric barrier discharge device includes a ground electrode 330, a power electrode 320, a dielectric barrier portion 340, and a mask portion 150.

- [214] The ground electrode 330 includes a depression 330a extending in a first direction and is electrically grounded. The power electrode 320 is buried in the depression 330a of the ground electrode 330, has a portion exposed to the outside, is applied with an AC voltage, and extends in the first direction. The dielectric barrier portion 340 is disposed in contact with the power electrode 320 to cover the exposed portion of the power electrode 320 and extends in the first direction. The mask portion 150 extends in the first direction, is disposed in a first area in which a target object 164 and the exposed portion of the power electrode 320 face each other, and spatially controls a plasma density to selectively perform a plasma treatment on the target object 164 according to a position of the first direction.
- [215] The power electrode 320 may be in the form of a cylinder, and the dielectric barrier portion 340 may be disposed to cover the circumference of the power electrode 320.
- [216] The ground electrode 330 may be in the form of a square pillar and may include a depression in which the power electrode 320 and the dielectric barrier portion 340 may be buried. The dielectric barrier portion 340 may be buried in an insulation block to exclude the exposed portion of the power electrode 320. A portion of the power electrode 320 may be exposed to an outer atmosphere with the dielectric barrier portion 340 interposed therebetween.
- [217] The insulation block may be in the form of a square pillar and may include a depression in which a portion of the power electrode 320 may be buried. A gas may be supplied to a space between the exposed portion of the power electrode 320 and the ground electrode 330.
- [218] A top surface of the ground electrode 330 may be a plane. An insulation plate 371 may be disposed on a top surface of the depression of the ground electrode 330. The mask portion 150 may be disposed on the insulation plate 371.
- [219] A gas distribution portion 332 may be disposed in the ground electrode 330. The gas distribution portion 332 may be formed in the ground electrode 330 to supply a gas along the exposed portion of the power electrode 320 at opposite sides of the power electrode 320. The gas distribution portion 332 may be connected to an internal side surface of the ground electrode 330 and may include slit-type or a plurality of nozzles extending in the first direction.
- [220] The gas distribution portion 332 may provide a fluid passage through which a gas flows. The gas distribution portion 332 may be connected to a buffer space 31 disposed in the ground electrode 330. The buffer space 331 may provide a diffusion space to spatially uniformly inject a gas. A gas is externally supplied to the buffer space 31.
- [221] A susceptor 162 is means for fixing or moving the target object 164, is formed of a conductor, and is grounded. The susceptor 162 may be in the form of a plate or a cylinder. The target object 164 may closely adhere to the susceptor 162. Dielectric

barrier discharge is generated between the susceptor 162 and the exposed portion of the power electrode 320.

[222] When a plasma treatment is desired to be selectively performed on only a specific portion such as a line pattern of the target object, the mask portion 150 may be disposed on an opening of the ground electrode 330.

[223] The mask portion 150 may have a pattern having a plurality of openings and may be formed of a ceramic material or a conductor. Preferably, the mask portion 150 may be formed of a conductor, may be grounded, and may be disposed to cover a top surface (or opening) of the depression of the ground electrode 330. The mask portion 150 may be in the form of a plate having a thickness of 1 millimeter or less and may include a plurality of openings arranged in the first direction. Preferably, the mask portion 150 is thin. The dielectric barrier portion 340 may be in substantial contact with a bottom surface of the mask portion 150. Since one area of the grounded conductive mask portion 150 and the dielectric barrier portion 340 are in contact with each other or do not provide a sufficient space, dielectric barrier discharge is not generated. In another opened area of the grounded conductive mask portion 150, the susceptor 162 and the exposed portion of the power electrode 320 perform dielectric barrier discharge. Thus, a plasma treatment may be selectively performed according to a position of the target object 164 as dielectric barrier discharge is locally generated in the first direction.

[224] Although the present disclosure and its advantages have been described in detail, it should be understood that various changes, substitutions and alterations can be made herein without departing from the spirit and scope of the disclosure as defined by the following claims.

[225]

## Claims

- [Claim 1] A dielectric barrier discharge device comprising:  
a ground electrode which includes a depression extending in a first direction and is electrically grounded;  
a power electrode which is buried in the depression of the ground electrode, has a portion exposed to the outside, is applied with an AC voltage, and extends in the first direction;  
a dielectric barrier portion which is disposed in contact with the power electrode to cover the exposed portion of the power electrode and extends in the first direction; and  
a mask portion which extends in the first direction, is disposed in a first area in which a target object and the exposed portion of the power electrode face each other, and spatially controls a plasma density to selectively perform a plasma treatment on the target object according to a position of the first direction.
- [Claim 2] The dielectric barrier discharge device as set forth in claim 1, wherein the mask portion has a thickness of 1 millimeter or less and includes a plurality of openings arranged in the first direction.
- [Claim 3] The dielectric barrier discharge device as set forth in claim 2, wherein the mask portion is formed of a conductor and is grounded, and the mask portion is disposed to cover a top surface of the depression of the ground electrode.
- [Claim 4] The dielectric barrier discharge device as set forth in claim 1, wherein the power electrode is in the form of a pillar having an edge extending in the first direction, and  
an edge of the power electrode is exposed to the outside.
- [Claim 5] The dielectric barrier discharge device as set forth in claim 4, further comprising:  
a gas distribution portion disposed in the ground electrode to supply a gas along the edge of the power electrode at opposite sides of the power electrode.
- [Claim 6] The dielectric barrier discharge device as set forth in claim 4, further comprising:  
a gas distribution portion disposed in the ground electrode to supply a gas to an inclined plane of the power electrode at opposite sides of the power electrode.
- [Claim 7] The dielectric barrier discharge device as set forth in claim 1, further



comprising:

a gas flow passage formed between the ground electrode and the dielectric barrier portion to supply a gas along an inclined plane of the power electrode at opposite sides of the power electrode, wherein a distance between the ground electrode and the dielectric barrier portion is 1 millimeter or less, and the gas flow passage performs auxiliary dielectric barrier discharge to provide plasma to the first area.

[Claim 8] The dielectric barrier discharge device as set forth in claim 1, further comprising:  
an insulation block provided in the form of a triangular pillar including of a depression,  
wherein the power electrode is in the form of a triangular prism, one edge of the power electrode is exposed to the outside, and the power electrode is disposed at the depression of the power electrode.

[Claim 9] The dielectric barrier discharge device as set forth in claim 8, wherein the ground electrode is disposed along an inclined plane of the power electrode and an inclined plane of the insulation block, the dielectric barrier portion is in the form of an L-shaped beam having a fixed thickness, and the dielectric barrier portion covers the inclined plane of the power electrode and a portion of the inclined plane of the insulation block.

[Claim 10] The dielectric barrier discharge device as set forth in claim 9, wherein the insulation block further includes a protrusion which extends in the first direction and protrudes to the inclined plane of the insulation block, and the dielectric barrier portion is disposed to be caught by the protrusion.

[Claim 11] The dielectric barrier discharge device as set forth in claim 9, wherein the ground electrode includes a ground electrode depression which is formed opposite to a lower side edge of the power electrode and extends in the first direction.

[Claim 12] The dielectric barrier discharge device as set forth in claim 11, further comprising:  
an arc prevention insulation block disposed at the ground electrode depression.

[Claim 13] The dielectric barrier discharge device as set forth in claim 11, wherein the ground electrode is disposed opposite to the power electrode, and

- the ground electrode further includes an auxiliary discharge ground electrode portion to provide an auxiliary discharge space between the ground electrode and the dielectric barrier portion.
- [Claim 14] The dielectric barrier discharge device as set forth in claim 8, wherein the ground electrode includes a winding ground electrode fluid passage which is formed therein and has a slit-type section.
- [Claim 15] The dielectric barrier discharge device as set forth in claim 1, wherein the mask portion includes a plurality of openings arranged in the first direction, and  
a size of the opening is between several hundreds of micrometers and several centimeters.
- [Claim 16] The dielectric barrier discharge device as set forth in claim 8, wherein the ground electrode further includes a bottom plate ground electrode where the insulation block is disposed,  
the bottom plate ground electrode includes a first trench which is formed on a top surface of the bottom plate ground electrode, is disposed adjacent to a side extending in the first direction, and extends in the first direction and a second trench which is spaced apart from the first trench to be disposed adjacent to a side of an opposite direction, the first trench includes a plurality of first gas inlets;  
the second trench includes a plurality of second gas inlets, and  
the first gas inlet and the second gas inlet are alternately disposed in the first direction.
- [Claim 17] The dielectric barrier discharge device as set forth in claim 1, wherein the dielectric barrier portion is chamfered on the edge of the power electrode such that a dielectric thickness is relatively reduced to cause strong plasma discharge between the target objects.
- [Claim 18] The dielectric barrier discharge device as set forth in claim 8, wherein the power electrode is in the form of a cylinder, and  
The dielectric barrier portion is disposed to cover a circumference of the power electrode.
- [Claim 19] The dielectric barrier discharge device as set forth in claim 1, wherein the exposed portion of the power electrode has an uneven structure according to a position of the first direction.
- [Claim 20] The dielectric barrier discharge device as set forth in claim 1, wherein one surface of the ground electrode facing the power electrode has an uneven structure according to a position of the first direction.
- [Claim 21] A dielectric barrier discharge device comprising:

a ground electrode which includes a depression extending in a first direction and is electrically grounded;  
a power electrode which is buried in the depression of the ground electrode, has a portion exposed to the outside, is applied with an AC voltage, and extends in the first direction; and  
a dielectric barrier portion which is disposed in contact with the power electrode to cover the exposed portion of the power electrode and extends in the first direction,  
wherein the exposed portion of the power electrode has an uneven structure which is disposed in a first area in which a target object and the exposed portion of the power electrode face each other, and spatially controls a plasma density to selectively perform a plasma treatment on the target object according to a position of the first direction.

- [Claim 22] The dielectric barrier discharge device as set forth in claim 21, further comprising:  
a mask portion which extends in the first direction, is disposed in the first area in which the target object and the exposed portion of the power electrode face each other, and spatially controls a plasma density to selectively perform a plasma treatment on the target object according to a position of the first direction.
- [Claim 23] The dielectric barrier discharge device as set forth in claim 22, wherein the mask portion includes a plurality of openings arranged in the first direction, and  
the opening is aligned with a protrusion of the uneven structure.
- [Claim 24] The dielectric barrier discharge device as set forth in claim 22, wherein the mask portion has a thickness of 1 millimeter or less and includes a plurality of openings arranged in the first direction.
- [Claim 25] The dielectric barrier discharge device as set forth in claim 22, wherein the mask portion is formed of a conductor and is grounded, and  
the mask portion is disposed to cover a top surface of the bend portion of the ground electrode.
- [Claim 26] The dielectric barrier discharge device as set forth in claim 21, wherein the power electrode is in the form of a pillar having an edge extending in the first direction, and  
the edge of the power electrode is exposed to the outside.
- [Claim 27] The dielectric barrier discharge device as set forth in claim 26, further comprising:

a gas discharge portion formed in the ground electrode to supply a gas along the edge of the power electrode at opposite sides of the power electrode.

[Claim 28] The dielectric barrier discharge device as set forth in claim 26, further comprising:

a gas flow passage formed between the ground electrode and the dielectric barrier portion to supply a gas along the edge of the power electrode at opposite sides of the power electrode,

wherein a distance between the ground electrode and the dielectric barrier portion is 1 millimeter or less, and

the gas flow passage performs auxiliary dielectric barrier discharge to provide plasma to the first area.

[Claim 29] The dielectric barrier discharge device as set forth in claim 26, further comprising:

an insulation block provided in the form of a truncated triangular prism, the power electrode is in the form of a triangular prism, one edge of the power electrode is exposed to the outside, and the power electrode is disposed at a truncated portion of the insulation block.

[Claim 30] The dielectric barrier discharge device as set forth in claim 29, wherein the ground electrode is disposed along an inclined plane of the power electrode and an inclined plane of the insulation block, the dielectric barrier portion is in the form of an L-shaped beam having a fixed thickness, and

the dielectric barrier portion covers the inclined plane of the power electrode and a portion of the inclined plane of the insulation block.

[Claim 31] The dielectric barrier discharge device as set forth in claim 30, wherein the insulation block further includes a protrusion which extends in the first direction and protrudes to the inclined plane of the insulation block, and

the dielectric barrier portion is disposed to be caught by the protrusion.

[Claim 32] The dielectric barrier discharge device as set forth in claim 29, wherein the ground electrode includes a ground electrode depression which is formed opposite to a lower side edge of the power electrode and extends in the first direction.

[Claim 33] The dielectric barrier discharge device as set forth in claim 32, further comprising:

an arc prevention insulation block disposed at the ground electrode de-

pression.

[Claim 34]

A dielectric barrier discharge device comprising:

a ground electrode which includes a depression extending in a first direction and is electrically grounded;

a power electrode which is buried in the depression of the ground electrode, has a portion exposed to the outside, is applied with an AC voltage, and extends in the first direction; and

a dielectric barrier portion which is disposed in contact with the power electrode to cover the exposed portion of the power electrode and extends in the first direction,

wherein the ground electrode provides an auxiliary discharge area facing an electrode power supply around the exposed portion of the power electrode,

one surface of the ground electrode facing the electrode power supply has an uneven structure to spatially control a plasma density in the auxiliary discharge area, and

plasma is provided from the auxiliary discharge area to selectively perform a plasma treatment in a main discharge area between the target object and the power electrode according to a position of the first direction.

[Claim 35]

The dielectric barrier discharge device as set forth in claim 34, further comprising:

a mask portion which extends in the first direction, is disposed in a main discharge area in which the target object and the exposed portion of the power electrode face each other, and spatially controls a plasma density to selectively perform a plasma treatment on the target object according to a position of the first direction.

[Claim 36]

The dielectric barrier discharge device as set forth in claim 35, wherein the mask portion includes a plurality of openings arranged in the first direction, and

the opening is aligned with a protrusion of the uneven structure of the ground electrode.

[Claim 37]

The dielectric barrier discharge device as set forth in claim 35, wherein the mask portion is formed of a conductor, is grounded, is in the form of a plate having a thickness of 1 millimeter or less, and include a plurality of openings arranged in the first direction.

[Claim 38]

The dielectric barrier discharge device as set forth in claim 35, wherein the mask portion is formed of a conductor and is grounded, and

the mask portion is disposed to cover a top surface of the depression of the ground electrode.

[Claim 39] The dielectric barrier discharge device as set forth in claim 34, wherein the power electrode is in the form of a pillar having an edge extending in the first direction, and

the edge of the power electrode is exposed to the outside.

[Claim 40] The dielectric barrier discharge device as set forth in claim 39, further comprising:

a gas distribution unit formed in the ground electrode to supply a gas along the edge of the power electrode at opposite sides of the power electrode.

[Claim 41] The dielectric barrier discharge device as set forth in claim 39, further comprising:

a gas flow passage formed between the ground electrode and the dielectric barrier portion to supply a gas along the edge of the power electrode at opposite sides of the power electrode,

wherein a distance between the ground electrode and the dielectric barrier portion is 1 millimeter or less, and

the gas flow passage performs auxiliary dielectric barrier discharge to provide plasma to the main discharge area.

[Claim 42] The dielectric barrier discharge device as set forth in claim 39, further comprising:

an insulation block provided in the form of a truncated triangular prism, the power electrode is in the form of a triangular prism, one edge of the power electrode is exposed to the outside, and the power electrode is disposed at a truncated portion of the insulation block.

[Claim 43] The dielectric barrier discharge device as set forth in claim 42, wherein the ground electrode is disposed along an inclined plane of the power electrode and an inclined plane of the insulation block,

the dielectric barrier portion is in the form of an L-shaped beam having a fixed thickness, and

the dielectric barrier portion covers the inclined plane of the power electrode and a portion of the inclined plane of the insulation block.

[Claim 44] The dielectric barrier discharge device as set forth in claim 43, wherein the insulation block further includes a protrusion which extends in the first direction and protrudes to the inclined plane of the insulation block, and

- the dielectric barrier portion is disposed to be caught by the protrusion.
- [Claim 45] The dielectric barrier discharge device as set forth in claim 42, wherein the ground electrode includes a ground electrode depression which is formed opposite to a lower side edge of the power electrode and extends in the first direction.
- [Claim 46] The dielectric barrier discharge device as set forth in claim 45, further comprising:  
an arc prevention insulation block disposed at the ground electrode depression.
- [Claim 47] A dielectric barrier discharge device comprising:  
a ground electrode which includes a depression extending in a first direction and is electrically grounded;  
a power electrode which is buried in the depression, has a portion exposed to the outside, is applied with an AC voltage, and extends in the first direction; and  
a dielectric barrier portion which is disposed in contact with the power electrode to cover the exposed portion of the power electrode, and extends in the first direction,  
wherein main discharge plasma is generated in a first area, which extends in the first direction and in which a target object and the exposed portion of the power electrode face each other, to treat the target object, and  
auxiliary discharge plasma is generated in a second area facing the first area between the ground electrode and the power electrode and supplies a gas of the second area to the first area to stably generate the main discharge plasma.
- [Claim 48] The dielectric barrier discharge device as set forth in claim 47, further comprising:  
a mask portion which extends in the first direction, is disposed in a first area in which the target object and the exposed portion of the power electrode face each other, and spatially controls a plasma density to selectively perform a plasma treatment on the target object according to a position of the first direction.
- [Claim 49] The dielectric barrier discharge device as set forth in claim 48, wherein the mask portion has a thickness of 1 millimeter or less and includes a plurality of openings arranged in the first direction.
- [Claim 50] The dielectric barrier discharge device as set forth in claim 48, wherein the mask portion is formed of a conductor and is grounded, and

the mask portion is disposed to cover a top surface of the depression of the ground electrode.

[Claim 51] The dielectric barrier discharge device as set forth in claim 47, wherein the power electrode is in the form of a pillar having an edge extending in the first direction, and

the edge of the power electrode is exposed to the outside.

[Claim 52] The dielectric barrier discharge device as set forth in claim 47, further comprising:

a gas distribution portion formed in the ground electrode to supply a gas along the edge of the power electrode at opposite sides of the power electrode.

[Claim 53] The dielectric barrier discharge device as set forth in claim 47, further comprising:

a gas flow passage formed between the ground electrode and the dielectric barrier portion to supply a gas along the edge of the power electrode at opposite sides of the power electrode,

wherein a distance between the ground electrode and the dielectric barrier portion is 1 millimeter or less, and

the gas flow passage performs auxiliary dielectric barrier discharge to provide plasma to the first area.

[Claim 54] The dielectric barrier discharge device as set forth in claim 51, further comprising:

an insulation block provided in the form of a truncated triangular prism, wherein the power electrode is in the form of a triangular prism, one edge of the power electrode is exposed to the outside, and the power electrode is disposed at a truncated portion of the insulation block.

[Claim 55] The dielectric barrier discharge device as set forth in claim 55, wherein the ground electrode is disposed along an inclined plane of the power electrode and an inclined plane of the insulation block,

the dielectric barrier portion is in the form of an L-shaped beam having a fixed thickness, and

the dielectric barrier portion covers the inclined plane of the power electrode and a portion of the inclined plane of the insulation block.

[Claim 56] The dielectric barrier discharge device as set forth in claim 55, further comprising:

a protrusion which extends in the first direction and protrudes to the inclined plane of the insulation block,



wherein the dielectric barrier portion is disposed to be caught by the protrusion.

[Claim 57]

The dielectric barrier discharge device as set forth in claim 54, further comprising:

a ground electrode depression which is formed opposite to a lower side edge of the power electrode and extends in the first direction.

[Claim 58]

The dielectric barrier discharge device as set forth in claim 57, further comprising:

an arc prevention insulation block disposed at the ground electrode depression.

[Claim 59]

A separator film plasma processing device of a secondary cell, comprising:

a ground electrode which includes a depression extending in a first direction and is electrically grounded;

a power electrode which is buried in the depression of the ground electrode, has a portion exposed to the outside, is applied with an AC voltage, and extends in the first direction;

a dielectric barrier portion which is disposed in contact with the power electrodes to cover the exposed portion of the power electrode and extends in the first direction; and

a mask portion which is disposed in a first area in which a separator film of a secondary cell extending in the first direction and the exposed portion of the power electrode face each other and spatially controls a plasma density to selectively perform a plasma treatment on the target object according to a position of the first direction.

[Claim 60]

An atmospheric dielectric discharge plasma processing method comprising:

providing transfer means which transfers a target object and is electrically grounded;

transferring the target object through the transfer means under an atmospheric pressure;

supplying AC power to a power electrode which is buried in the ground electrode and has an exposed portion; and

performing a spatially selective plasma treatment on the target object by disposing a dielectric discharge portion to cover the exposed portion of the power electrode and disposing a mask on the dielectric discharge portion.

[Claim 61]

The atmospheric dielectric discharge plasma processing method as set

forth in claim 60, further comprising:

generating auxiliary dielectric discharge between the ground electrode and the exposed portion of the power electrode.

[Claim 62]

The atmospheric dielectric discharge plasma processing method as set forth in claim 60, further comprising:

supplying a process gas to the exposed portion of the power electrode via the ground electrode,

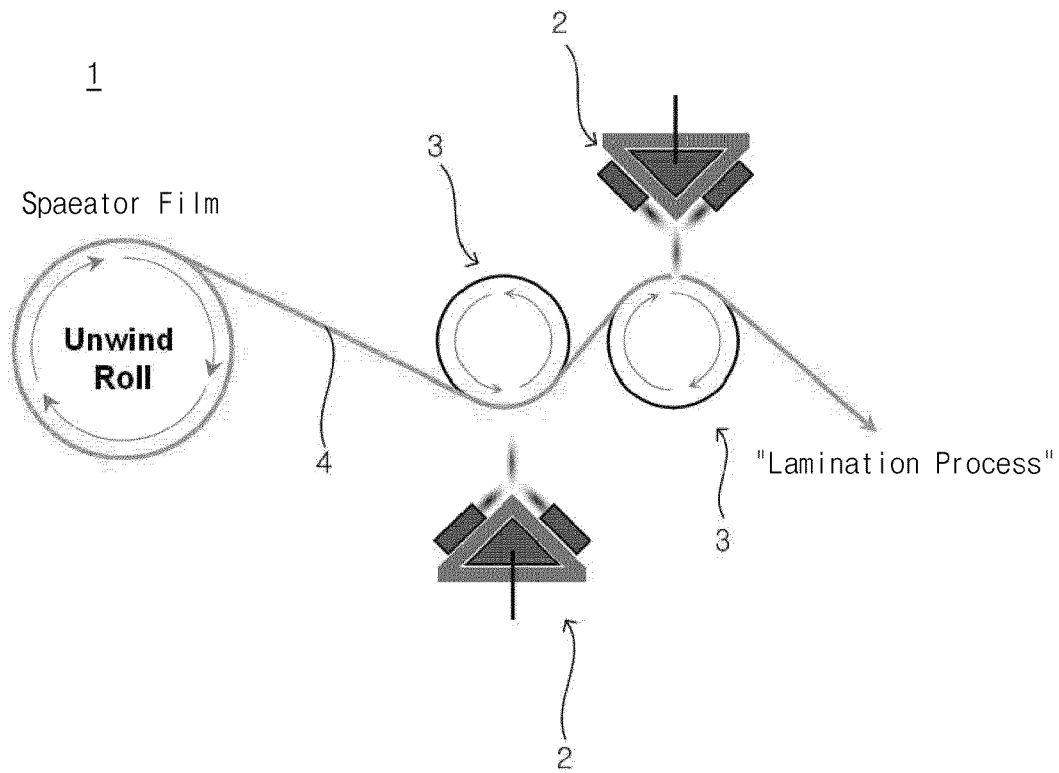
wherein the plasma hydrophilically treats the target object, and

the process gas includes at least one of oxygen, nitrogen, hydrogen, and argon.

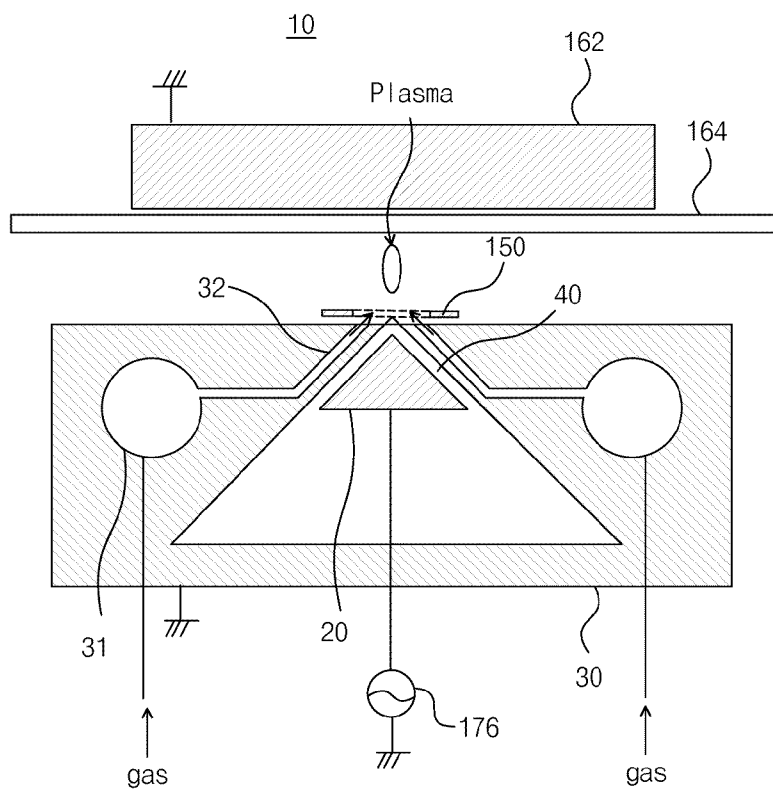
[Claim 63]

The atmospheric dielectric discharge plasma processing method as set forth in claim 60, wherein the target object is a separator film of a secondary cell.

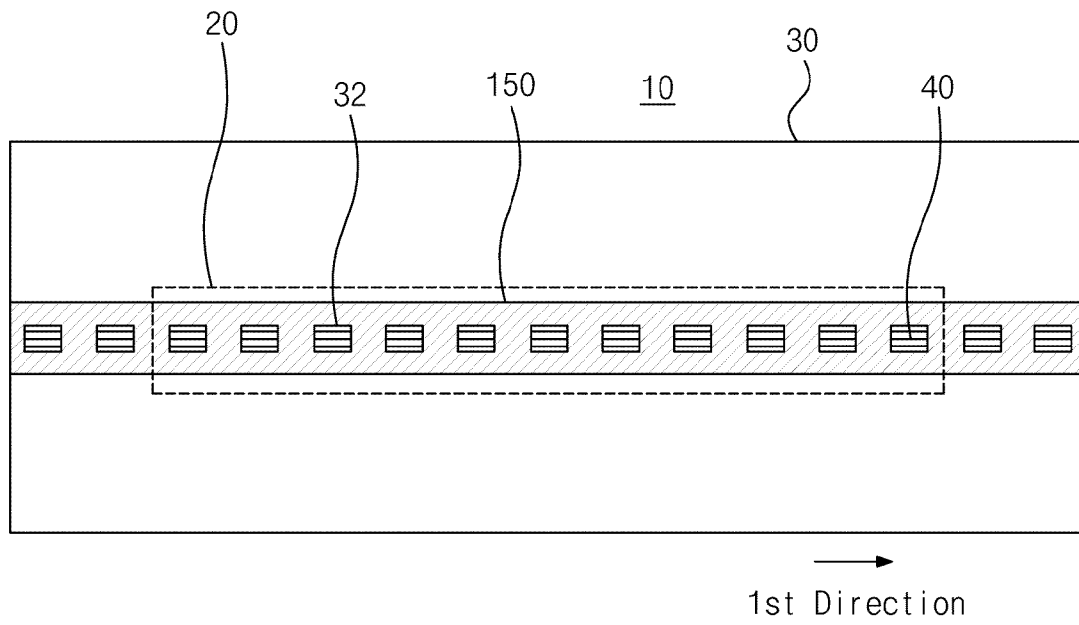
[Fig. 1]



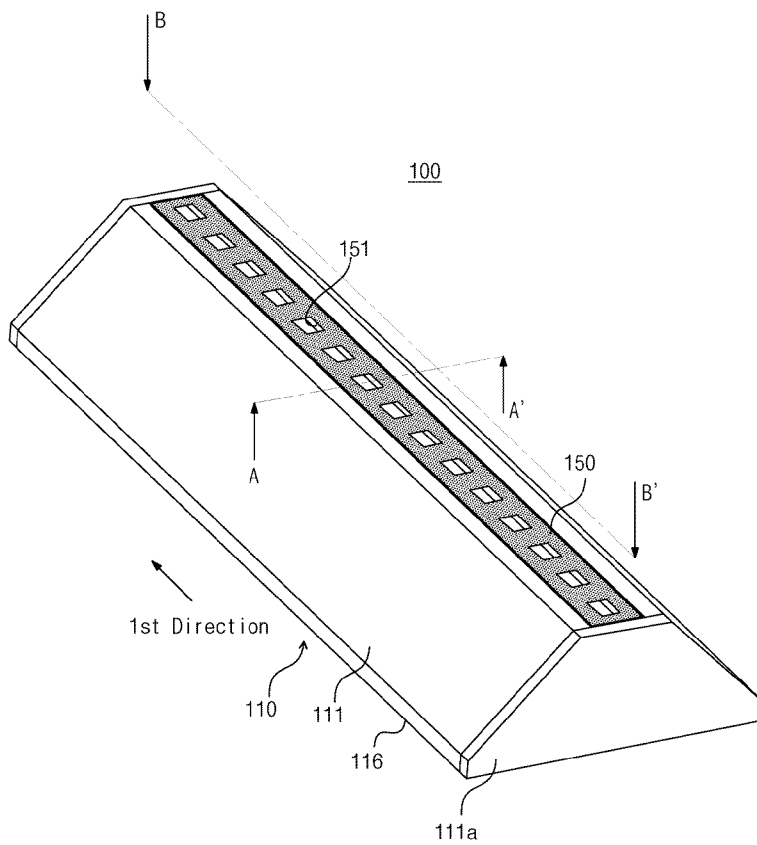
[Fig. 2a]



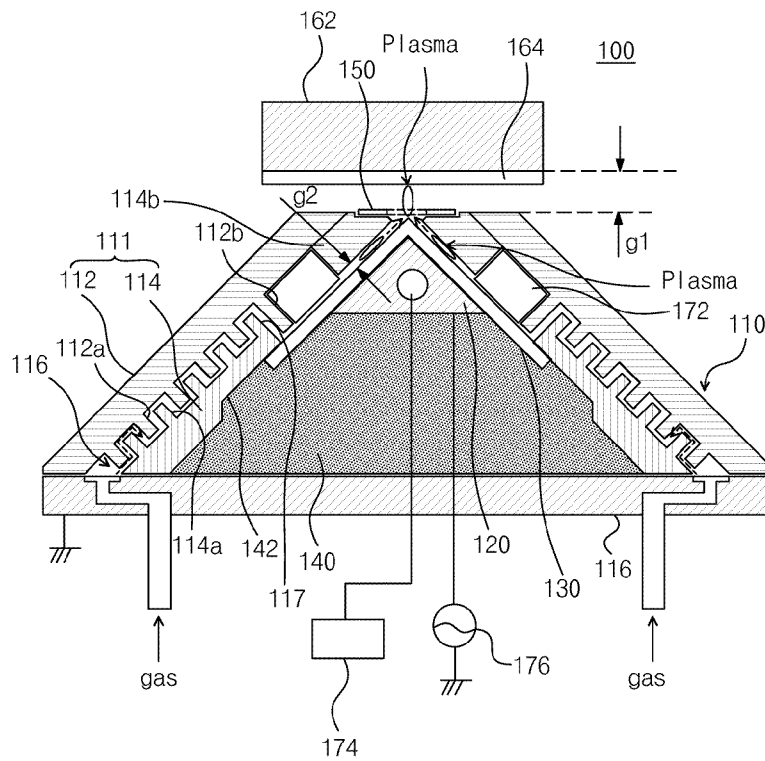
[Fig. 2b]



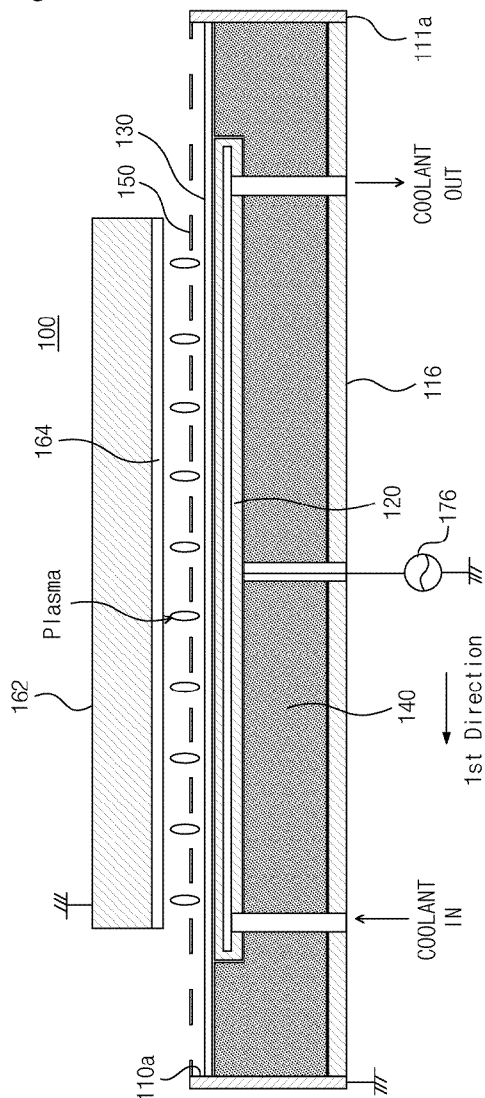
[Fig. 3a]



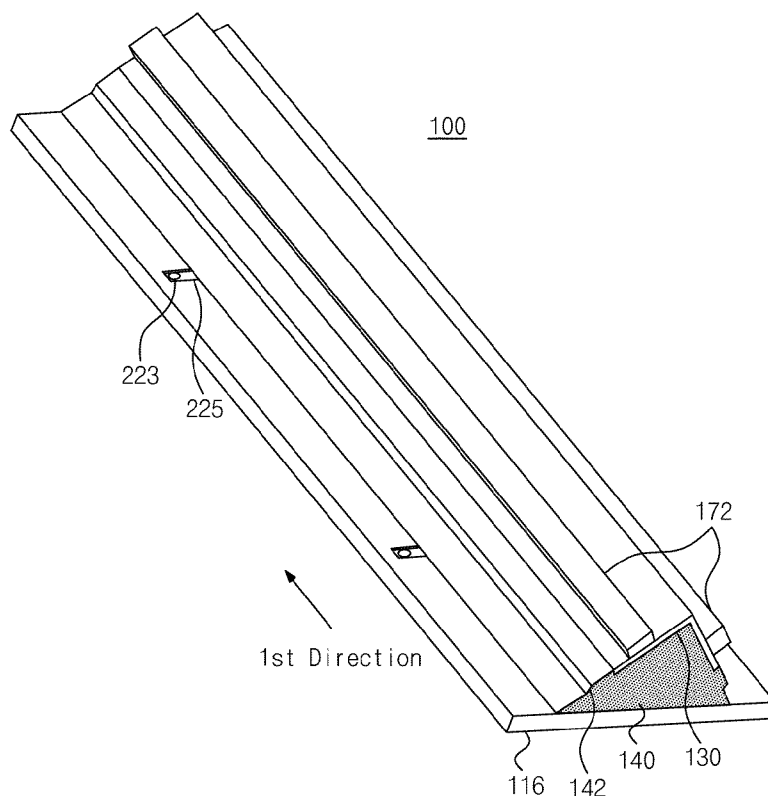
[Fig. 3b]



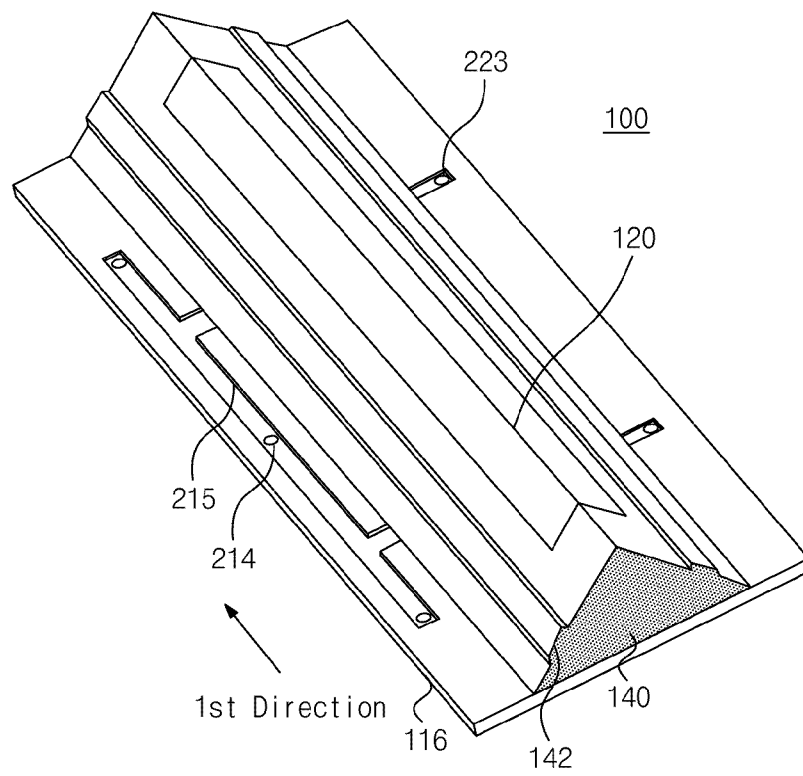
[Fig. 3c]



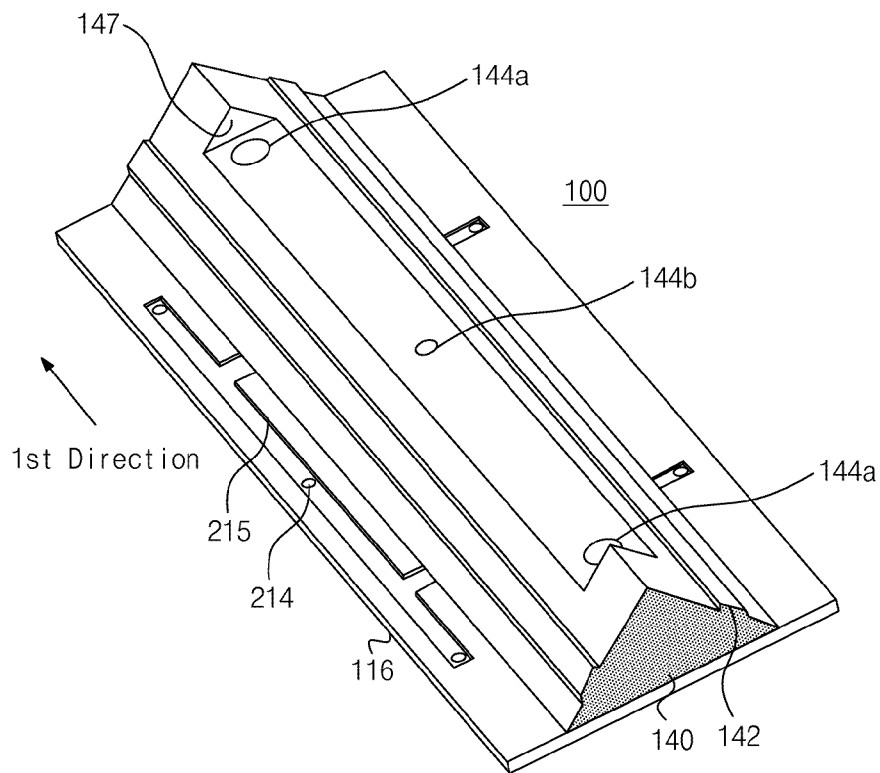
[Fig. 3d]



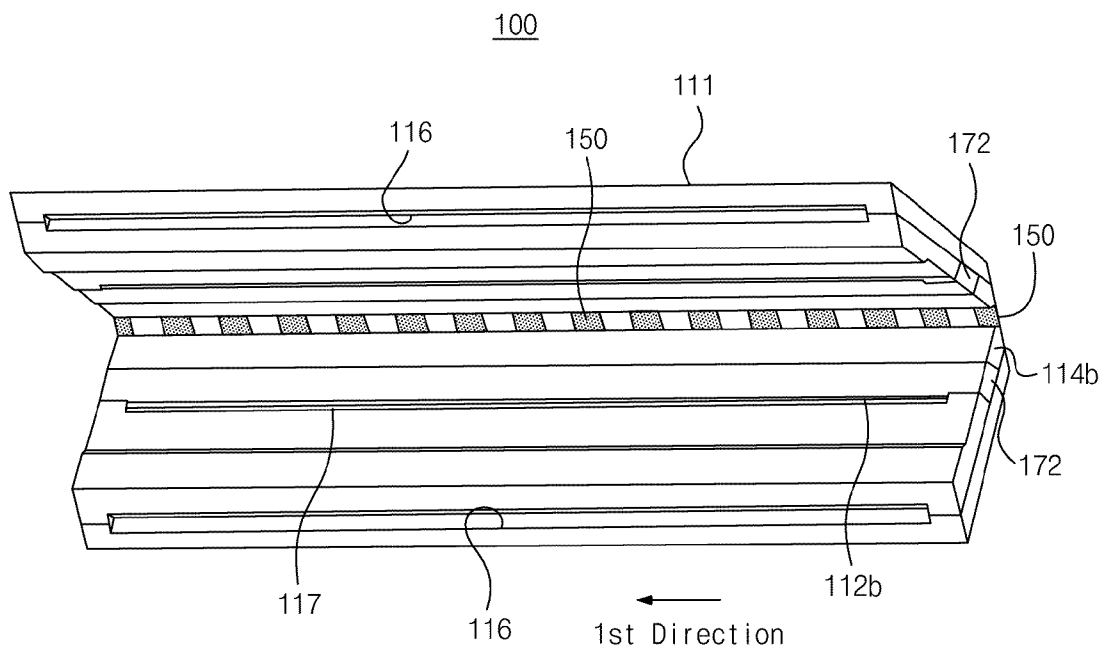
[Fig. 3e]



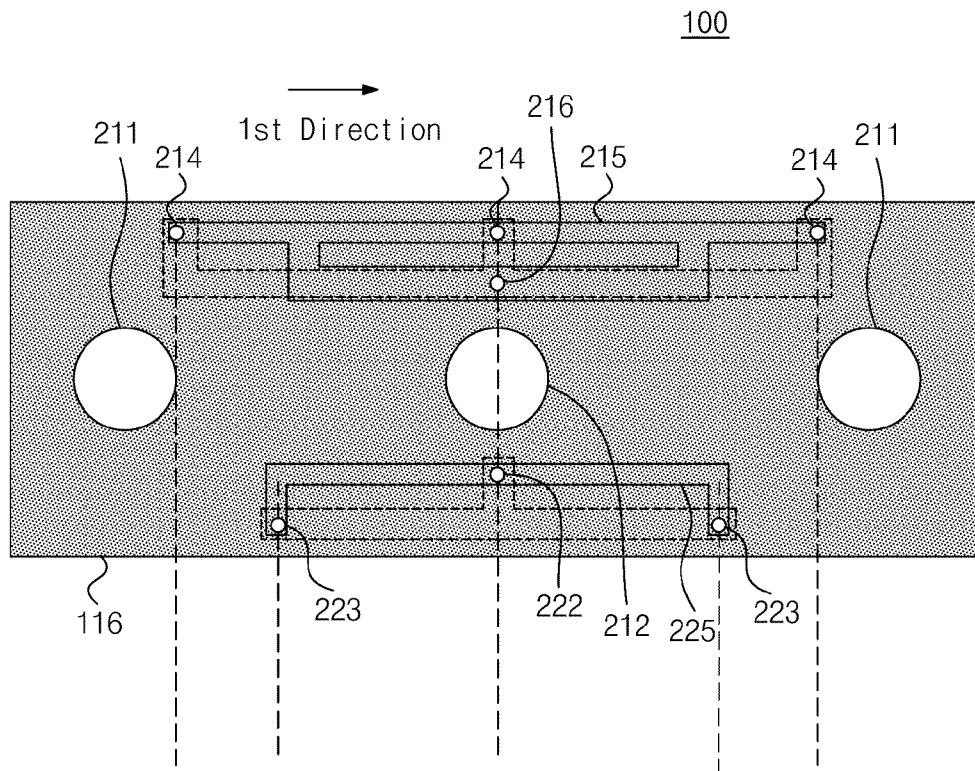
[Fig. 3f]



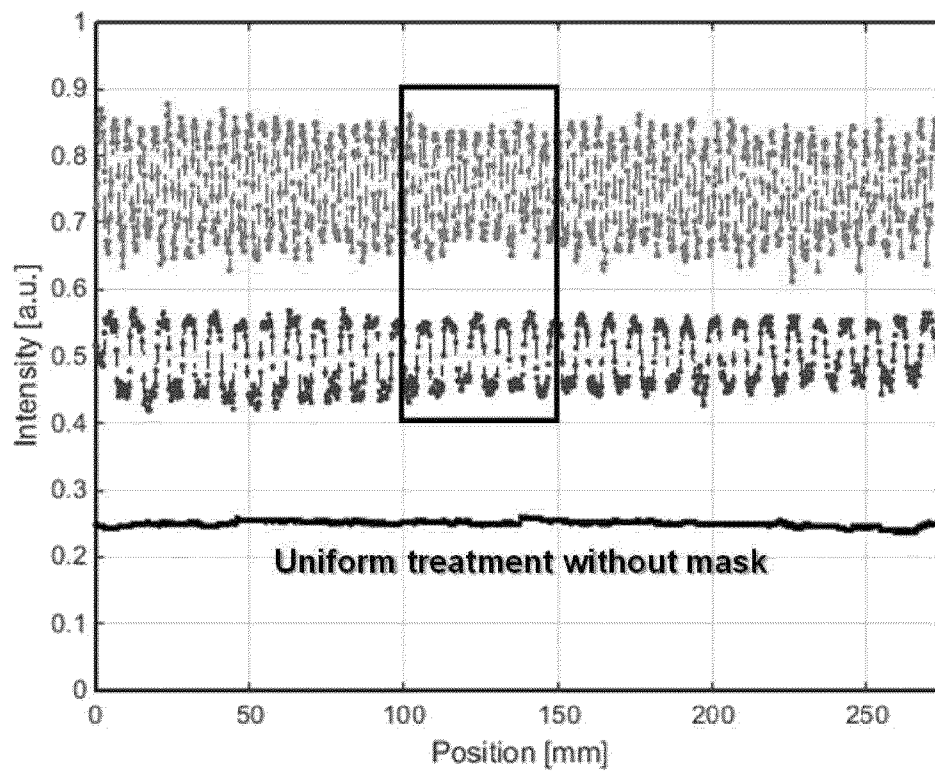
[Fig. 3g]



[Fig. 3h]

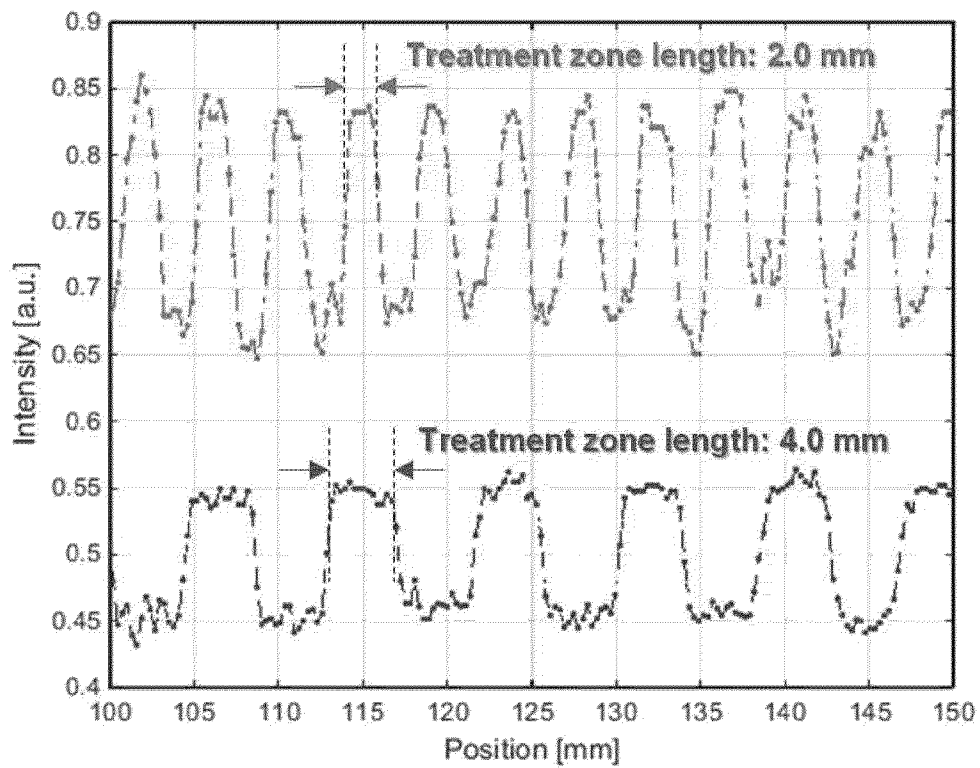


[Fig. 4a]

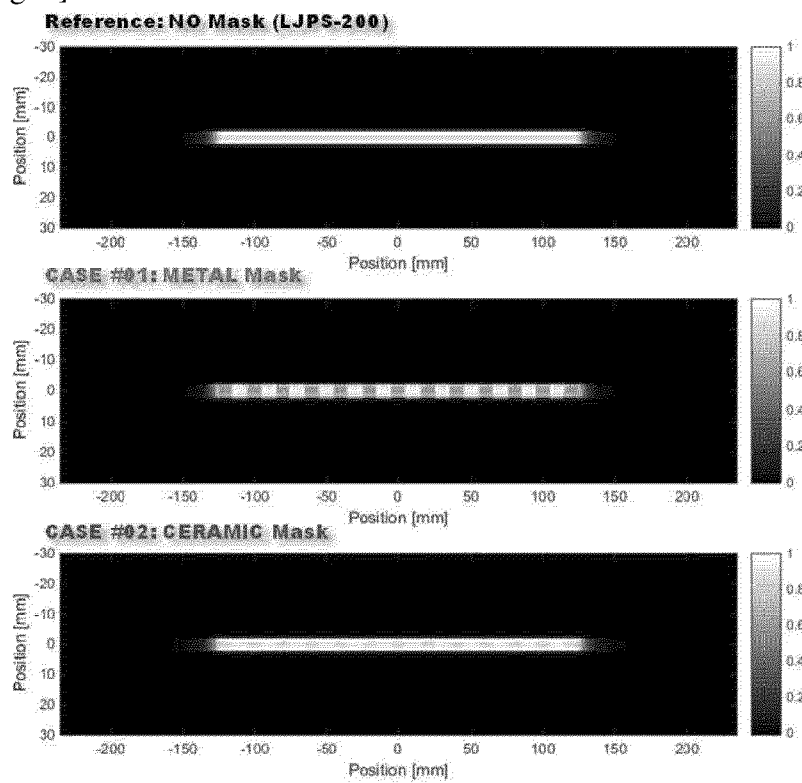




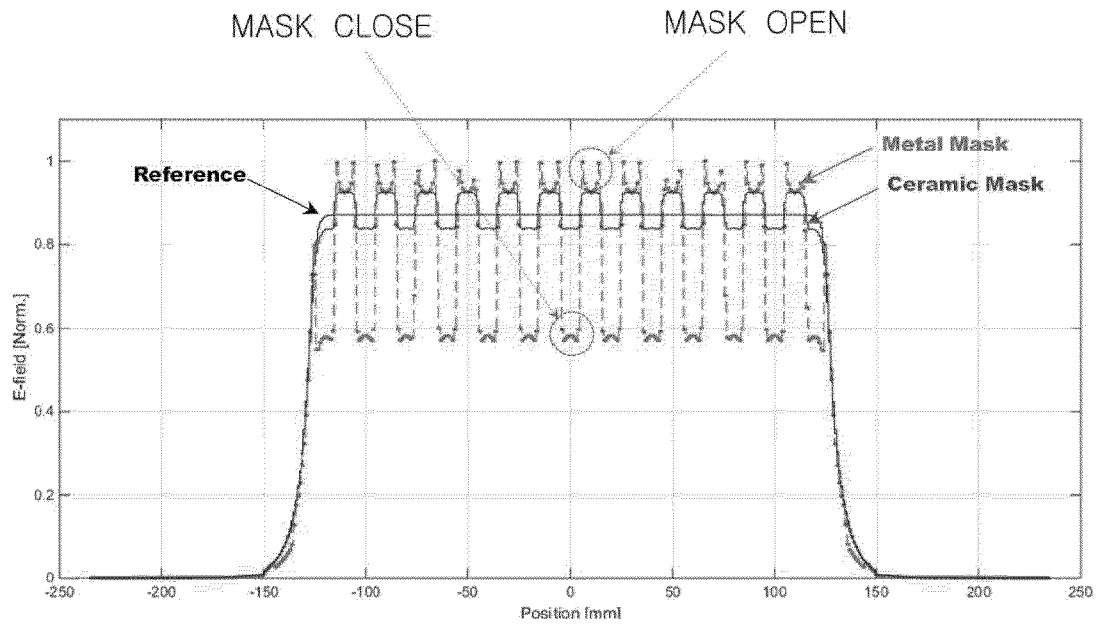
[Fig. 4b]



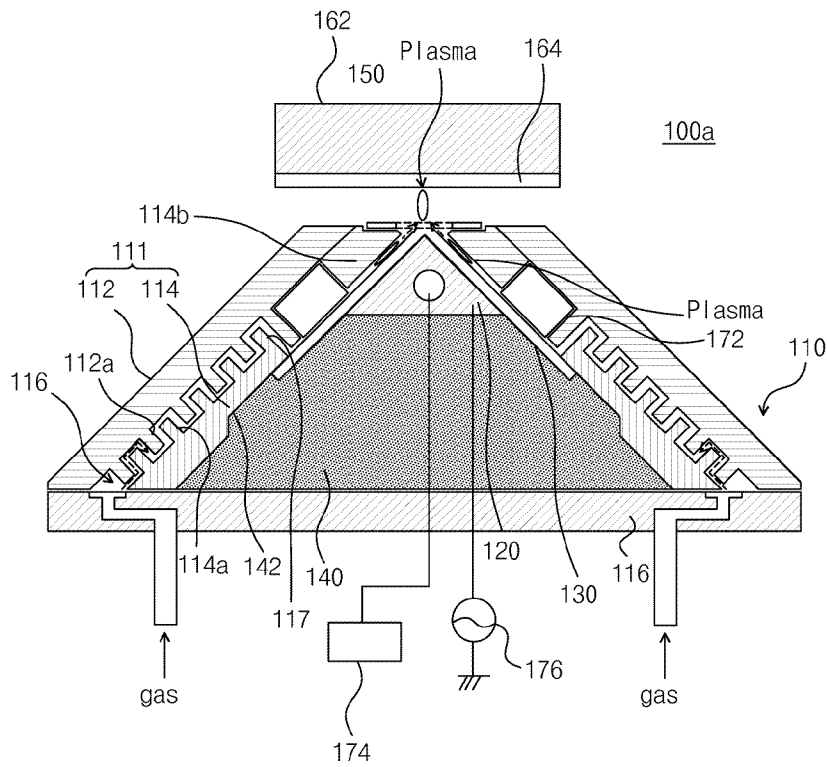
[Fig. 5]



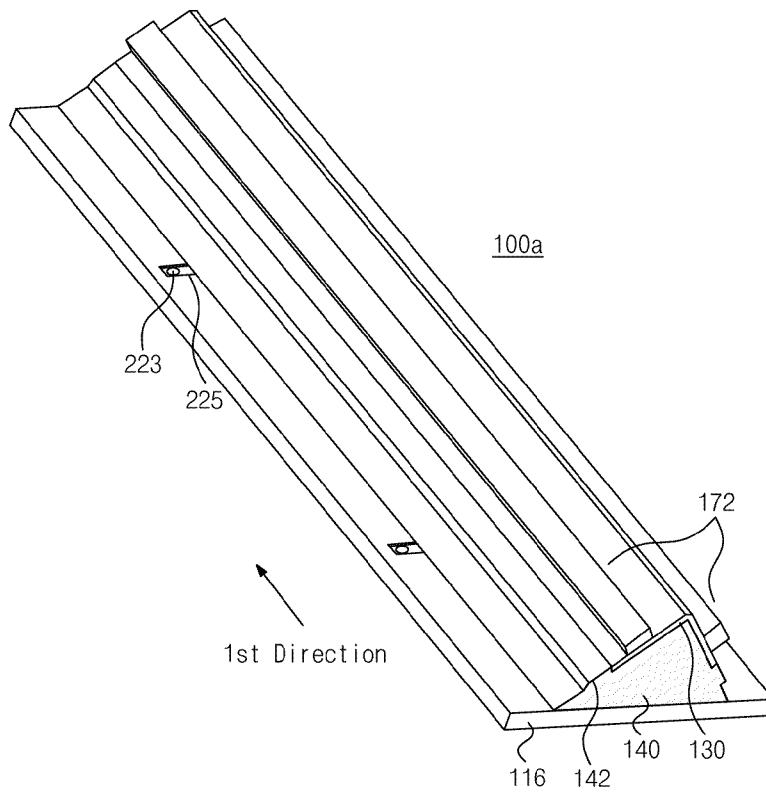
[Fig. 6]



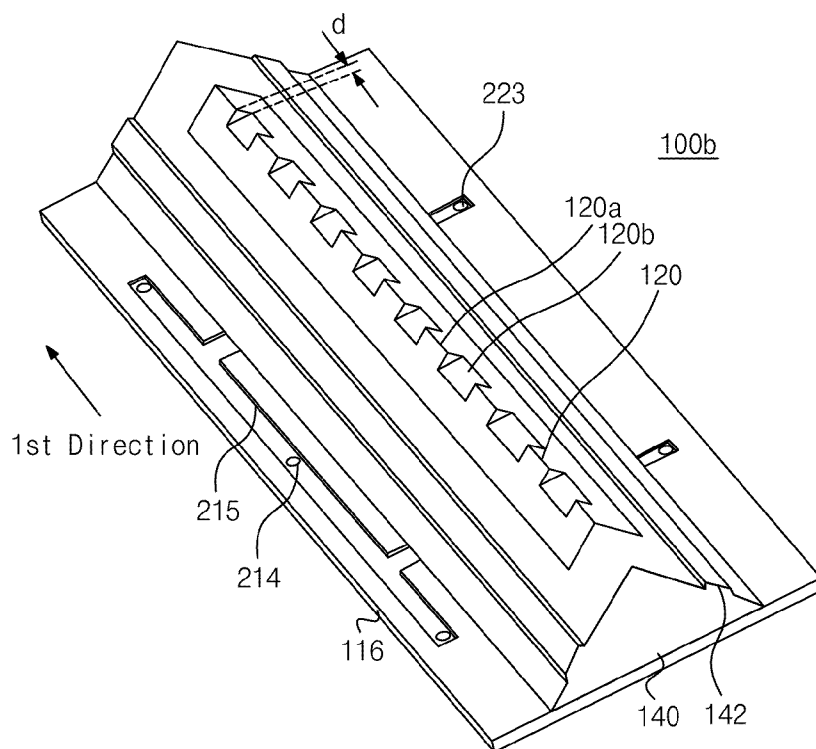
[Fig. 7a]



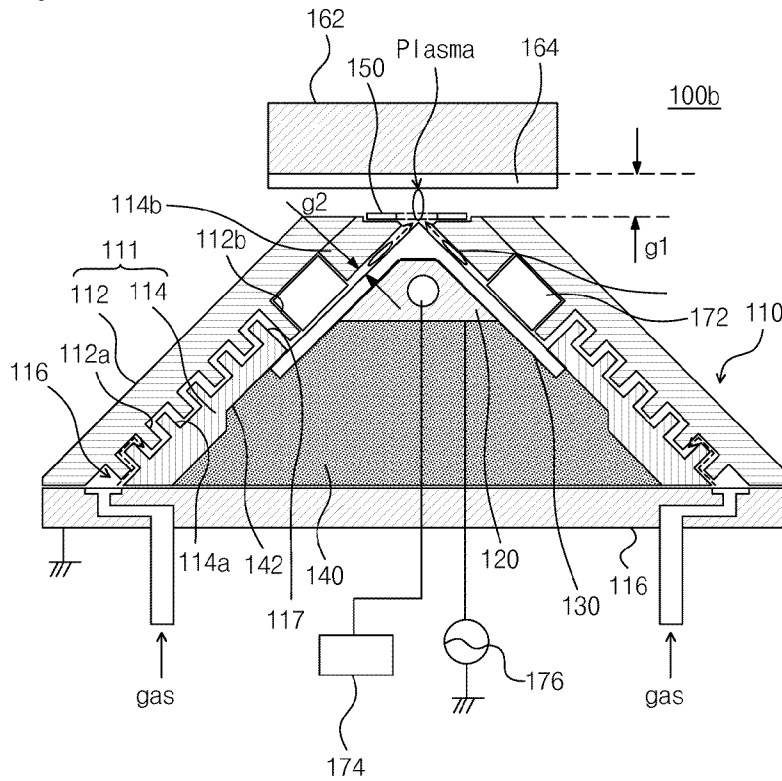
[Fig. 7b]



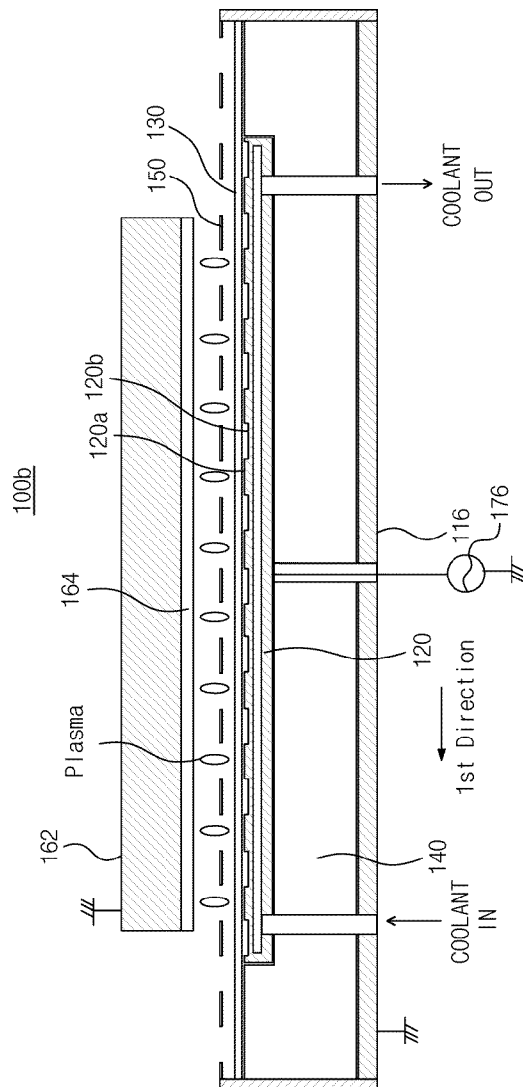
[Fig. 8a]



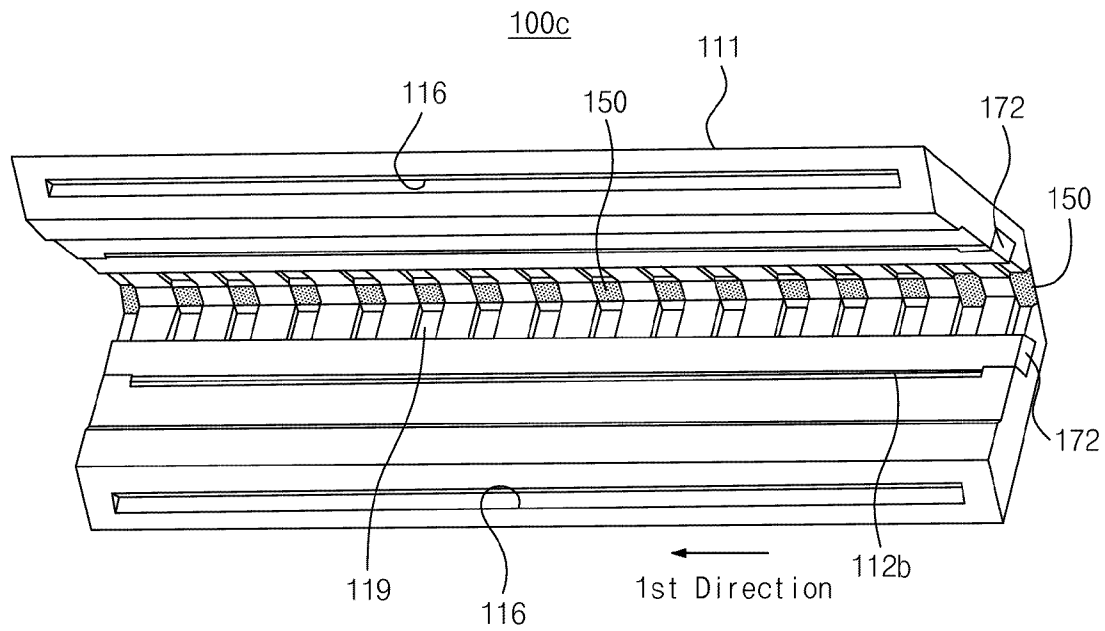
[Fig. 8b]



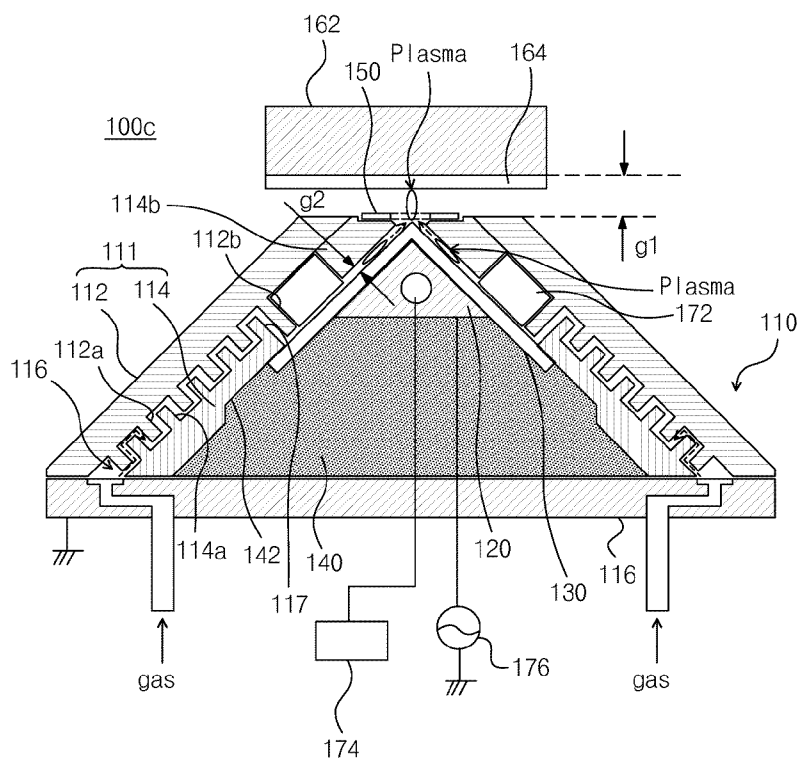
[Fig. 8c]



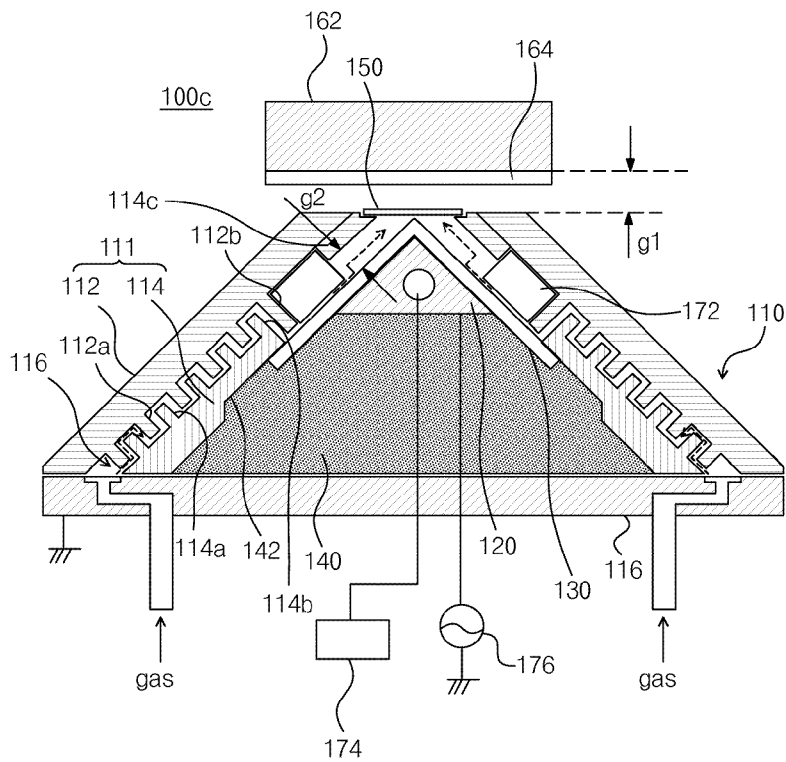
[Fig. 9a]



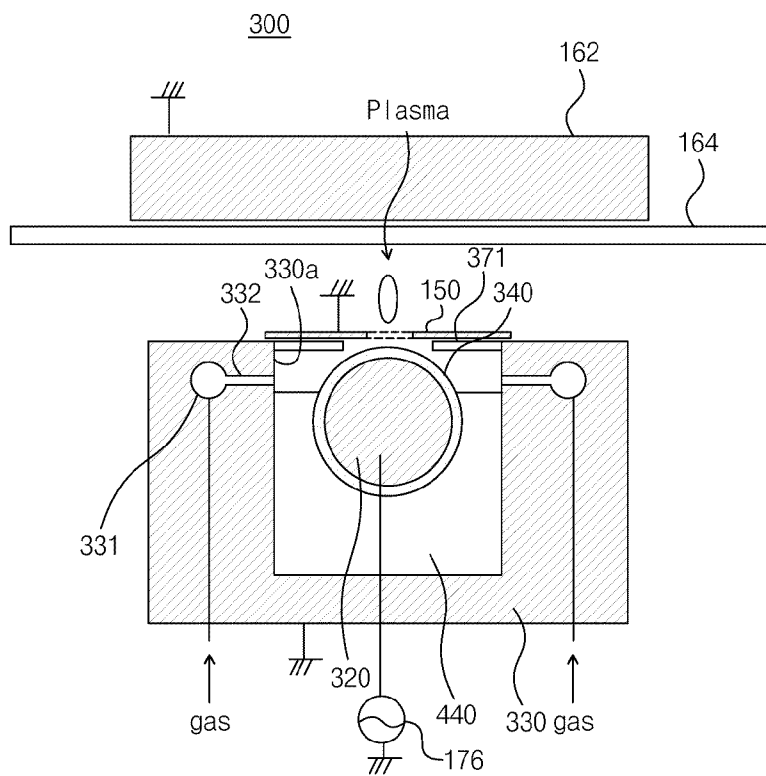
[Fig. 9b]



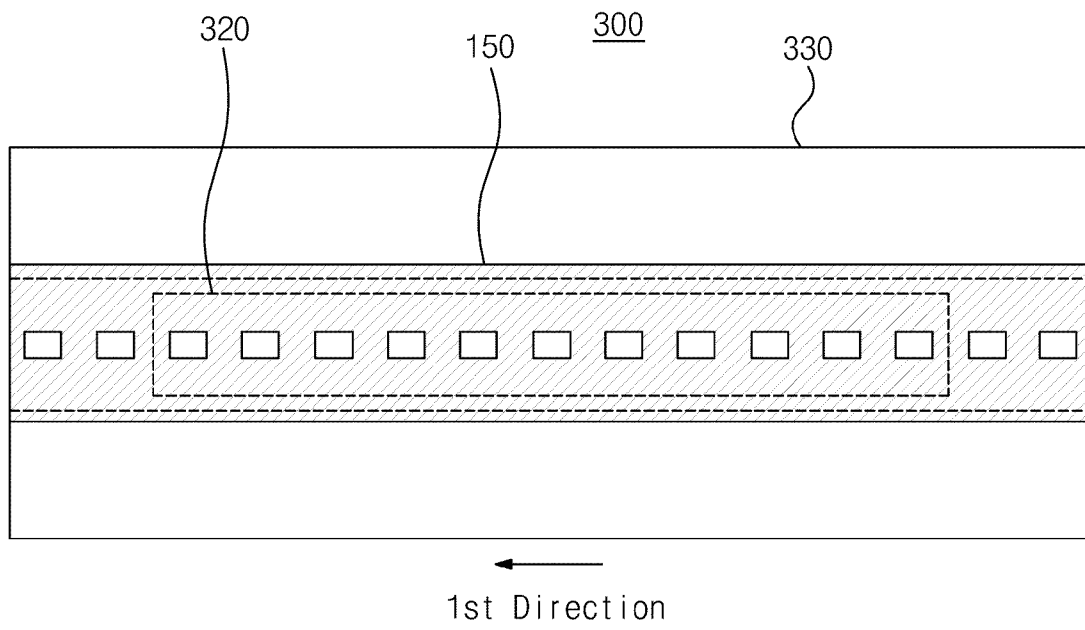
[Fig. 9c]



[Fig. 10a]



[Fig. 10b]



## INTERNATIONAL SEARCH REPORT

International application No.  
**PCT/KR2016/015255****A. CLASSIFICATION OF SUBJECT MATTER****H05H 1/24(2006.01)i, H05H 1/46(2006.01)i, H01J 37/32(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

H05H 1/24; H05H 1/46; H01L 21/3065; C23F 4/00; B08B 7/00; H01L 21/02; B01J 19/08; C23C 16/00; H01J 37/32

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) &amp; keywords: dielectric barrier discharge device, plasma, ground electrode, power electrode, mask

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                  | Relevant to claim No. |
|-----------|-------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| Y         | JP 2002-018276 A (PEARL KOGYO K.K.) 22 January 2002<br>See paragraphs [0006]-[0021], claim 1 and figures 4-5.                       | 1-18,47-59            |
| A         |                                                                                                                                     | 19-46,60-63           |
| Y         | US 2013-0206720 A1 (PAULUS PETRUS MARIA BLOM et al.) 15 August 2013<br>See paragraphs [0069]-[0154], claims 1, 40, 42 and figure 1. | 1-18,47-63            |
| Y         | US 2006-0096539 A1 (SHINICHI KAWASAKI et al.) 11 May 2006<br>See paragraph [0005] and claims 60-63.                                 | 60-63                 |
| A         | KR 10-1030712 B1 (GLOBAL TECHNOLOGY VIDEO CO., LTD.) 26 April 2011<br>See claims 1-7 and figure 1.                                  | 1-63                  |
| A         | JP 2001-087643 A (PEARL KOGYO K.K.) 03 April 2001<br>See claims 1-5 and figure 4.                                                   | 1-63                  |



Further documents are listed in the continuation of Box C.



See patent family annex.

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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Date of the actual completion of the international search

07 April 2017 (07.04.2017)

Date of mailing of the international search report

**07 April 2017 (07.04.2017)**

Name and mailing address of the ISA/KR

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**INTERNATIONAL SEARCH REPORT**

Information on patent family members

International application No.

**PCT/KR2016/015255**

| Patent document<br>cited in search report | Publication<br>date | Patent family<br>member(s)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Publication<br>date                                                                                                                                                                                                                                                                                                                                                                    |
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