

DESCRIPTION

DISCHARGE DEVICE AND METHOD FOR MANUFACTURING SAME

5 TECHNICAL FIELD

[0001]

The present invention relates to a discharge device and a method for manufacturing the same, and more specifically, to a discharge device including a discharge electrode and a voltage application unit that applies a voltage to
10 the discharge electrode, and a method for manufacturing the same.

BACKGROUND ART

[0002]

Conventionally, discharge devices each including a discharge electrode
15 and a voltage application unit are provided. As discharge devices, the following devices are known: a device that applies a voltage to a discharge electrode by a voltage application unit to produce corona discharge at the discharge electrode and generate atmospheric ions; and a device that supplies liquid to the discharge electrode, produces corona discharge in the discharge
20 electrode, and generates a charged corpuscle liquid containing radicals (for example, refer to PTL 1).

Citation List

Patent Literature

[0003]

25 PTL 1: Unexamined Japanese Patent Publication No. 2011-67738

SUMMARY

[0004]

Discharge devices have a request for raising energy to inject and increasing generation amounts of atmospheric ions, radicals, and charged corpuscle liquids including atmospheric ions and radicals (atmospheric ions, radicals, and charged corpuscle liquids are hereinafter collectively referred to as "active components"), and a request for suppressing ozone production at this time. However, it is difficult for the conventional discharge devices to satisfy both of the two requests.

[0005]

Embodiments of the present disclosure propose a discharge device that can increase generation amounts of active components and suppress an increase in ozone at this time, and a method for manufacturing the same.

[0006]

The discharge device of an aspect includes a discharge electrode, a voltage application unit that applies a voltage to the discharge electrode to produce discharge that has further developed from corona discharge in the discharge electrode, an opposite electrode positioned facing the discharge electrode. The discharge electrode is configured to receive higher energy than corona discharge to produce a discharge path in which dielectric breakdown occurs so as to extend around from the discharge electrode, wherein the discharge electrode is configured to produce the discharge path in which dielectric breakdown occurs to connect between the discharge electrode and the opposite electrode, and

wherein the opposite electrode includes a needle-shaped electrode part facing the discharge electrode,

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[0007]

By producing such high-energy discharge, generation amounts of active components can be increased as compared with corona discharge, and an increase in ozone can be suppressed.

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[0007a] According to an aspect, there is a discharge device comprising:

a discharge electrode;

a voltage application unit that applies a voltage to the discharge electrode to produce discharge that has further developed from corona discharge in the discharge electrode;

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an opposite electrode positioned facing the discharge electrode,

wherein the discharge electrode is configured to produce a discharge path in which dielectric breakdown occurs so as to extend around from the discharge electrode,

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wherein the discharge electrode is configured to produce the discharge path in which dielectric breakdown occurs to connect between the discharge electrode and the opposite electrode, and

, wherein

the opposite electrode includes:

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at least one acute protruding surface facing the discharge electrode; and

an opposite surface facing the discharge electrode, and

the opposite surface has a flat surface, a concave surface, or a shape in which the flat surface and the concave surface are combined.

25

[0008]

The discharge device of the present disclosure produces effects of increasing generation amounts of active components and suppressing an

increase in ozone at this time.

BRIEF DESCRIPTION OF DRAWINGS

[0009]

5 FIG. 1 is a schematic diagram showing a discharge device of a first exemplary embodiment.

 FIG. 2A is a graph schematically showing a current flowing by corona discharge.

 FIG. 2B is a graph schematically showing a current flowing by leader
10 discharge.

 FIG. 3A is a schematic diagram showing a discharge device of a second exemplary embodiment.

 FIG. 3B is a schematic diagram showing a modified example of the discharge device.

15 FIG. 4A is a schematic diagram showing a discharge device of a third exemplary embodiment.

 FIG. 4B is a schematic diagram showing a modified example of the discharge device.

 FIG. 5 is a schematic diagram showing a discharge device of a fourth
20 exemplary embodiment.

 FIG. 6A is a perspective view showing main parts of a discharge device of a fifth exemplary embodiment.

 FIG. 6B is a perspective view showing main parts of a discharge device of a sixth exemplary embodiment.

25 FIG. 6C is a perspective view showing main parts of a discharge device of a seventh exemplary embodiment.

 FIG. 7 is a perspective view showing a discharge device of an eighth

exemplary embodiment.

FIG. 8 is a plan view showing the discharge device.

FIG. 9 is a sectional side view showing the discharge device.

FIG. 10A is a plan view showing a modified example of the discharge
5 device.

FIG. 10B is a plan view showing another modified example of the
discharge device.

FIG. 11 is a plan view showing a main part of another modified
example of the discharge device.

10 FIG. 12A is a side view showing main parts of another modified
example of the discharge device.

FIG. 12B is an enlarged view of section A of FIG. 12A.

FIG. 13 is a cross-sectional view showing a process of forming a needle-
shaped electrode part of the modified example shown in FIGS. 12A and 12B.

15 FIG. 14 is a perspective view showing main parts of another modified
example of the discharge device.

FIG. 15A is a bottom view showing a discharge device of a ninth
exemplary embodiment.

20 FIG. 15B is a perspective view showing the discharge device with a lid
provided.

FIG. 16 is a perspective view showing a modified example of the
discharge device.

FIG. 17 is a perspective view showing another modified example of the
discharge device.

25 FIG. 18A is a graph showing a relationship between a wire length
between an opposite electrode and a resistor, and an amount of active
components.

FIG. 18B is a graph showing a relationship between a wire length between a voltage application unit and a resistor, and the amount of active components.

FIG. 19 is a schematic diagram showing a device that performs
5 measurement of graph charts of FIGS. 18A and 18B.

FIG. 20 is a plan view showing main parts of a discharge device of a tenth exemplary embodiment.

FIG. 21 is a cross-sectional view taken along line 21-21 of FIG. 20.

FIG. 22 is a cross-sectional taken along the line 22-22 of FIG. 20.

10 FIG. 23 is a block diagram showing main parts of a discharge device of an eleventh exemplary embodiment.

FIG. 24 is a block diagram showing main parts of a modified example of the discharge device.

15 DESCRIPTION OF EMBODIMENTS

[0010]

A first aspect of the present invention is a discharge device including a discharge electrode, and a voltage application unit that applies a voltage to the discharge electrode to produce discharge that has further developed from
20 corona discharge at the discharge electrode. The discharge is discharge that intermittently produces a discharge path in which dielectric breakdown occurs so as to extend around from the discharge electrode. This can increase a generation amount of active components and inhibit an increase in ozone.

[0011]

25 A second aspect of the present invention is, in particular, the first aspect of the present invention including a liquid supply unit that supplies liquid to the discharge electrode. The liquid supplied to the discharge

electrode is electrostatically atomized by the discharge. This can increase a generation amount of charged corpuscle liquid and inhibit an increase in ozone.
[0012]

A third aspect of the present invention is, in particular, the first or
5 second aspect of the present invention including an opposite electrode positioned facing the discharge electrode. The discharge is discharge that intermittently produces the discharge path in which dielectric breakdown occurs to connect between the discharge electrode and the opposite electrode. This makes it possible to stably produce the discharge that intermittently
10 produces the discharge path in which dielectric breakdown occurs between the discharge electrode and the opposite electrode.
[0013]

A fourth aspect of the present invention is, in particular, the third aspect of the present invention in which the opposite electrode includes a
15 needle-shaped electrode part facing the discharge electrode. This makes it possible to stably produce the discharge that intermittently produces the discharge path in which dielectric breakdown occurs between the discharge electrode and the needle-shaped electrode part.
[0014]

20 A fifth aspect of the present invention is, in particular, the fourth aspect of the present invention in which the needle-shaped electrode part includes a distal end portion and a proximal end portion on opposite sides, the discharge electrode has an axial direction, and a distance between the distal end portion and the discharge electrode in the axial direction is smaller than a
25 distance between the proximal end portion and the discharge electrode in the axial direction. This makes it possible to stably produce the discharge that intermittently produces the discharge path in which dielectric breakdown

occurs between the discharge electrode and the needle-shaped electrode part.

[0015]

A sixth aspect of the present invention is, in particular, the fifth aspect of the present invention in which the opposite electrode includes: a supporting
5 electrode part held in a posture orthogonal to the axial direction; and a step portion that lies between the supporting electrode part and the needle-shaped electrode part. A distance between the proximal end portion and the discharge electrode in the axial direction is larger than a distance between the supporting electrode part and the discharge electrode in the axial direction.

10 This can suppress large protrusion of the distal end portion of the needle-shaped electrode part and inhibit deformation of the needle-shaped electrode part.

[0016]

A seventh aspect of the present invention is, in particular, one of the
15 fourth to sixth aspects of the present invention in which the needle-shaped electrode part includes a groove part for inhibiting deformation of the needle-shaped electrode part, and the groove part is formed by a portion of the needle-shaped electrode part bending in a thickness direction of the needle-shaped electrode part. This can increase geometrical moment of inertia of the needle-
20 shaped electrode part, and inhibit deformation of the needle-shaped electrode part.

[0017]

An eighth aspect of the present invention is, in particular, the fourth aspect of the present invention in which the opposite electrode further includes
25 a supporting electrode part that supports the needle-shaped electrode part, and the needle-shaped electrode part and the supporting electrode part are members of materials different from each other. This can enhance tolerance

of the needle-shaped electrode part to leader discharge while suppressing cost increase.

[0018]

5 A ninth aspect of the present invention is, in particular, one of the fourth to eighth aspects of the present invention in which the opposite electrode includes a plurality of the needle-shaped electrode parts. This allows generated active components to be efficiently released outside.

[0019]

10 A tenth aspect of the present invention is, in particular, the ninth aspect of the present invention in which distal end portions of the plurality of needle-shaped electrode parts are positioned on an identical circle. This allows generated active components to be more efficiently released outside.

[0020]

15 An eleventh aspect of the present invention is, in particular, the tenth aspect of the present invention in which the distal end portions of the plurality of needle-shaped electrode parts are equally spaced from each other in a circumferential direction of the identical circle. This allows generated active components to be more efficiently released outside.

[0021]

20 A twelfth aspect of the present invention is, in particular, one of the ninth to eleventh aspects of the present invention in which each of the plurality of needle-shaped electrode parts includes a distal end portion having a rounded shape. This suppresses generation of large variation in intensity of electric field concentration caused by manufacturing variation of the plurality
25 of needle-shaped electrode parts.

[0022]

A thirteenth aspect of the present invention is, in particular, one of the

ninth to twelfth aspects of the present invention in which each of the plurality of needle-shaped electrode parts is a piece-shaped electrode part having a thickness, and in an edge portion of a thickness direction of each of the plurality of needle-shaped electrode parts, a portion close to the discharge electrode is chamfered. This will suppress generation of large variation in intensity of electric field concentration caused by manufacturing variation of the plurality of needle-shaped electrode parts.

[0023]

A fourteenth aspect of the present invention is, in particular, one of the ninth to thirteenth aspects of the present invention in which the plurality of needle-shaped electrode parts is three or more needle-shaped electrode parts spaced from each other. This allows generated active components to be more efficiently released outside.

[0024]

A fifteenth aspect of the present invention is, in particular, the fourteenth aspect of the present invention in which the opposite electrode further includes an opening in which the three or more needle-shaped electrode parts are disposed, and an opening area of the opening is larger than a total area of the three or more needle-shaped electrode parts. This allows easy development from corona discharge to leader discharge.

[0025]

A sixteenth aspect of the present invention is, in particular, the third aspect of the present invention in which the opposite electrode includes: at least one acute protruding surface facing the discharge electrode; and an opposite surface facing the discharge electrode, and the opposite surface has a flat surface, a concave surface, or a shape in which the flat surface and the concave surface are combined. This allows electric field concentration to

easily occur at the distal end portion of the discharge electrode.

[0026]

A seventeenth aspect of the present invention is, in particular, one of the first to sixteenth aspects of the present invention further including a capacitor that is electrically connected in parallel to the voltage application unit. This allows a discharge frequency of leader discharge to be adjusted.

[0027]

An eighteenth aspect of the present invention is, in particular, a method for manufacturing the discharge device of the thirteenth aspect of the present invention, the method including crushing the edge portion of the thickness direction of each of the plurality of needle-shaped electrode parts at one time on one surface of a mold device to perform the chamfering. This allows positions of the distal end portions of the plurality of needle-shaped electrode parts to be aligned at one time.

[0028]

Exemplary embodiments of the present invention will be described below with reference to the drawings. Note that the present invention is not limited to the exemplary embodiments to be described below, and it is also possible to suitably combine configurations of the following exemplary embodiments.

[0029]

(First exemplary embodiment)

FIG. 1 shows a basic configuration of a discharge device of a first exemplary embodiment. The discharge device of the present exemplary embodiment includes discharge electrode 1, voltage application unit 2, liquid supply unit 3, opposite electrode 4, and current-carrying path 5.

[0030]

Discharge electrode 1 is a slenderly formed needle-shaped electrode. Discharge electrode 1 includes distal end portion 13 on one end side of an axial direction of discharge electrode 1, and proximal end portion 15 on the other end side of the axial direction (opposite side of distal end portion 13). The
5 wording of needle-shaped used herein is not limited to an object with a keenly sharp distal end, and includes a case where the distal end is rounded.

[0031]

Voltage application unit 2 is electrically connected to discharge electrode 1 to apply a high voltage of about 7.0 kV to discharge electrode 1.
10 The discharge device of the present exemplary embodiment includes opposite electrode 4. Voltage application unit 2 is configured to apply the high voltage between discharge electrode 1 and opposite electrode 4.

[0032]

Liquid supply unit 3 is a unit to supply liquid 35 for electrostatic
15 atomization to discharge electrode 1. In the discharge device of the present exemplary embodiment, cooler 30 that cools discharge electrode 1 to generate dew condensation water constitutes liquid supply unit 3. Cooler 30 is in contact with proximal end portion 15 of discharge electrode 1, and cools overall discharge electrode 1 through proximal end portion 15. Liquid 35 that liquid
20 supply unit 3 supplies to discharge electrode 1 is dew condensation water generated in discharge electrode 1.

[0033]

Opposite electrode 4 is positioned facing distal end portion 13 of discharge electrode 1. Opposite electrode 4 has opening 43 in a central
25 portion of opposite electrode 4. Opening 43 penetrates in a thickness direction of opposite electrode 4. Opening 43 is provided in an area closest to distal end portion 13 of discharge electrode 1 out of opposite electrode 4. The

direction in which opening 43 penetrates and the axial direction of discharge electrode 1 are parallel to each other. The wording of parallel used herein is not limited to strictly parallel, but includes generally parallel.

[0034]

5 Current-carrying path 5 is a current-carrying path that electrically connects opposite electrode 4 to discharge electrode 1. Voltage application unit 2 is disposed at a midpoint of current-carrying path 5. That is, current-carrying path 5 includes first current-carrying path 51 that electrically connects voltage application unit 2 to opposite electrode 4, and second current-carrying path 52 that electrically connects voltage application unit 2 to discharge electrode 1.

[0035]

 In the discharge device of the present exemplary embodiment, in a state where liquid 35 is held by discharge electrode 1, voltage application unit 2 applies the high voltage of about 7.0 kV between discharge electrode 1 and opposite electrode 4. This produces discharge between discharge electrode 1 and opposite electrode 4.

[0036]

 The discharge device of the present exemplary embodiment first produces local corona discharge at distal end portion 13 of discharge electrode 1 (distal end of liquid 35 held by distal end portion 13), and further develops this corona discharge to high-energy discharge. This high-energy discharge is discharge of a mode in which a discharge path is produced intermittently in which dielectric breakdown (all path breakdown) occurs so as to extend around from discharge electrode 1. In the discharge device of the present exemplary embodiment, the discharge path is produced intermittently (in pulses) in which dielectric breakdown occurs so as to connect discharge electrode 1 to

opposite electrode 4. Discharge of such a mode is referred to as "leader discharge".

[0037]

In leader discharge, an instantaneous current of about 2 times to 10
5 times larger than in corona discharge flows through the discharge path in
which dielectric breakdown occurs between discharge electrode 1 and opposite
electrode 4. FIG. 2A schematically shows a current flowing by corona
discharge, and FIG. 2B schematically shows a current flowing by leader
discharge that has developed from corona discharge. In leader discharge,
10 radicals are generated by energy larger than in corona discharge, and a large
amount of radicals, about 2 times to 10 times larger than in corona discharge
is generated.

[0038]

Ozone is also generated when radicals are generated by leader
15 discharge. However, in leader discharge, whereas a large amount of radicals,
about 2 times to 10 times larger than in corona discharge is generated, an
amount of ozone generation is suppressed to the same level as in corona
discharge. That is, by further developing corona discharge and producing
leader discharge, the amount of ozone generation with respect to the amount of
20 radical generation is significantly suppressed. This is considered because
part of ozone is destroyed by high-energy leader discharge when the generated
ozone is released while being exposed to leader discharge.

[0039]

Here, leader discharge will be further described.

25 [0040]

In general, when energy is injected between a pair of electrodes to
produce discharge, in accordance with an amount of injected energy, a

discharge mode develops to corona discharge, glow discharge, and arc discharge.

[0041]

Corona discharge is discharge that occurs locally in one electrode, and
5 is not accompanied by dielectric breakdown between the electrodes. Glow
discharge and arc discharge are discharge accompanied by dielectric
breakdown between a pair of electrodes, and while energy is injected, the
discharge path in which dielectric breakdown occurs exists continuously.

[0042]

10 In contrast, leader discharge is accompanied by dielectric breakdown
between a pair of electrodes, but the dielectric breakdown does not exist
continuously but occurs intermittently.

[0043]

In the discharge device of the present exemplary embodiment, electric
15 capacity of voltage application unit 2 (capacity of electricity that can be
released in unit time) is set to produce leader discharge of such a mode
between discharge electrode 1 and opposite electrode 4. That is, in the
discharge device of the present exemplary embodiment, the electric capacity of
voltage application unit 2 is set to repeat that when corona discharge develops
20 and results in dielectric breakdown, a large instantaneous current flows
through the discharge path in which dielectric breakdown occurs, and
immediately after the large instantaneous current flowing, the voltage drops
and the discharge stops, and the voltage rises again and results in dielectric
breakdown. By this capacity setting, leader discharge is achieved in which
25 instantaneous dielectric breakdown and discharge stop are repeated
alternately, instead of dielectric breakdown being continued as glow discharge
or arc discharge.

[0044]

As one example that can be confirmed under the current circumstances, a discharge frequency in leader discharge (how often an instantaneous current flows) is about 50 Hz to 10 kHz, and one pulse width is about 200 ns at most.

5 Thus, leader discharge is clearly different from glow discharge or arc discharge in that instantaneous discharge (high-energy state) and discharge stop (low-energy state) are repeated.

[0045]

In the discharge device of the present exemplary embodiment, liquid

10 supply unit 3 supplies liquid 35 to discharge electrode 1. Therefore, liquid 35 is electrostatically atomized by leader discharge with high energy accompanied by intermittent dielectric breakdown, generating the charged corpuscle liquid having a nanometer size and containing radicals. The generated charged corpuscle liquid is released outside through opening 43.

15 [0046]

The charged corpuscle liquid generated by leader discharge contains a larger amount of radicals than the charged corpuscle liquid generated by corona discharge, and moreover, generation of ozone is suppressed to the same extent as in corona discharge.

20 [0047]

As described above, the discharge device of the present exemplary embodiment described based on FIG. 1 and the like is a device including liquid supply unit 3 in order to generate the charged corpuscle liquid (electrostatic atomization device); however, the discharge device can be configured without

25 liquid supply unit 3. In this case, atmospheric ions are generated by leader discharge that occurs between discharge electrode 1 and opposite electrode 4.

[0048]

Also, the discharge device of the present exemplary embodiment includes opposite electrode 4, but can be configured without opposite electrode 4. In this case, when leader discharge is produced between discharge electrode 1 and some member around discharge electrode 1, the charged corpuscle liquid is generated by leader discharge. The discharge device of the present exemplary embodiment can include neither liquid supply unit 3 nor opposite electrode 4. In this case, when leader discharge is produced between discharge electrode 1 and some member around discharge electrode 1, atmospheric ions are generated by leader discharge.

10 [0049]

(Second exemplary embodiment)

A discharge device of a second exemplary embodiment will be described with reference to FIGS. 3A and 3B. Note that detailed descriptions of components similar to components described in the first exemplary embodiment will be omitted.

15 [0050]

FIG. 3A shows a basic configuration of the discharge device of the present exemplary embodiment. The discharge device of the present exemplary embodiment differs from the discharge device of the first exemplary embodiment in that opposite electrode 4 integrally includes needle-shaped electrode part 41 and supporting electrode part 42 that supports needle-shaped electrode part 41.

20 [0051]

Needle-shaped electrode part 41 is an electrode part protruding from opposite surface 420 facing discharge electrode 1 out of supporting electrode part 42 toward a side close to discharge electrode 1. Needle-shaped electrode part 41 has an acute protruding surface. Out of overall opposite electrode 4, a

distal end of needle-shaped electrode part 41 is closest to discharge electrode 1. Needle-shaped electrode part 41 is positioned near opening 43 of opposite electrode 4. The discharge device of the present exemplary embodiment includes one needle-shaped electrode part 41, but can include a plurality of
5 needle-shaped electrode parts 41.

[0052]

Supporting electrode part 42 includes electrode part 421 having a plate shape and including an opposite surface having a flat shape, and electrode part 422 having a dome shape and including an opposite surface having a
10 concave shape. Opposite surfaces of electrode part 421 and electrode part 422 constitute opposite surface 420 of supporting electrode part 42. Opposite surface 420 of supporting electrode part 42 has a shape in which the flat surface and the concave surface are combined.

[0053]

15 Since the discharge device of the present exemplary embodiment has the above-described configuration, electric field concentration occurs at needle-shaped electrode part 41 of opposite electrode 4 and distal end portion 13 of discharge electrode 1 (that is, distal end of liquid 35 held by distal end portion 13), stably producing leader discharge by dielectric breakdown between needle-
20 shaped electrode part 41 of opposite electrode 4 and distal end portion 13 of discharge electrode 1. In addition, electric field concentration at distal end portion 13 of discharge electrode 1 is further increased by opposite surface 420 of supporting electrode part 42.

[0054]

25 FIG. 3B shows a modified example of the discharge device of the present exemplary embodiment. In this modified example, supporting electrode part 42 includes electrode part 423 having a dome shape and

including an opposite surface having a concave shape. Opposite surface 420 of supporting electrode part 42 is a concave surface curved in a concave shape about distal end portion 13 of discharge electrode 1.

[0055]

5 This modified example also has an advantage that leader discharge by dielectric breakdown occurs stably between needle-shaped electrode part 41 of opposite electrode 4 and distal end portion 13 of discharge electrode 1, and an advantage that electric field concentration at distal end portion 13 of discharge electrode 1 is further increased. Note that opposite surface 420 of supporting electrode part 42 of opposite electrode 4 is required at least to be an appropriate flat surface, a concave surface, or a surface of a shape in which these surfaces are combined.

[0056]

(Third exemplary embodiment)

15 A discharge device of a third exemplary embodiment will be described with reference to FIGS. 4A and 4B. Note that detailed descriptions of components similar to components described in the first exemplary embodiment will be omitted.

[0057]

20 FIG. 4A shows the discharge device of the present exemplary embodiment. In the discharge device of the present exemplary embodiment, limiting resistor 6 for adjusting a current peak of leader discharge is provided at a midpoint of current-carrying path 5 electrically connecting discharge electrode 1 to opposite electrode 4. Specifically, in current-carrying path 5, limiting resistor 6 is disposed at a midpoint of first current-carrying path 51 electrically connecting voltage application unit 2 to opposite electrode 4.

[0058]

In leader discharge, an instantaneous current flows through a discharge path in which dielectric breakdown occurs, and current resistance at that time becomes very small. Therefore, in the discharge device of the present exemplary embodiment, limiting resistor 6 is provided in first current-carrying path 51 to suppress the current peak of the instantaneous current. Suppressing the current peak of the instantaneous current brings about an advantage that generation of NO_x is suppressed and an advantage that excessive influence of electrical noise is suppressed. Limiting resistor 6 is not limited to a configuration using a dedicated element, and any appropriate configuration can be employed when limiting resistor 6 has a structure having electric resistance according to the setting.

[0059]

FIG. 4B shows a modified example of the discharge device of the present exemplary embodiment. In this modified example, limiting resistor 6 is disposed at a midpoint of second current-carrying path 52 electrically connecting voltage application unit 2 to discharge electrode 1. Also in this modified example, the peak value of the instantaneous current of leader discharge is suppressed by limiting resistor 6.

[0060]

(Fourth exemplary embodiment)

A discharge device of a fourth exemplary embodiment will be described with reference to FIG. 5. Note that detailed descriptions of components similar to components described in the third exemplary embodiment will be omitted.

[0061]

In the discharge device of the present exemplary embodiment, capacitor 7 for adjusting a discharge frequency in leader discharge is disposed

at a midpoint of current-carrying path 5. Capacitor 7 is electrically connected in parallel to voltage application unit 2. As described above, since current resistance when an instantaneous current flows in leader discharge is extremely small, by disposing such capacitor 7 in current-carrying path 5, the discharge frequency of leader discharge is effectively adjusted.

[0062]

Capacitor 7 is not limited to a configuration using a dedicated element, and any appropriate configuration can be employed when capacitor 7 has a structure having capacitance according to the setting.

[0063]

(Fifth exemplary embodiment)

A discharge device of a fifth exemplary embodiment will be described with reference to FIG. 6A. Note that detailed descriptions of components similar to components described in the second exemplary embodiment will be omitted.

[0064]

In the discharge device of the present exemplary embodiment, as a unit for stably producing leader discharge accompanied by dielectric breakdown, needle-shaped electrode part 41 having an acute protruding surface is not provided as in the second exemplary embodiment, but two bar electrode parts 46 parallel to each other are integrally provided. Opposite electrode 4 has opening 43 having a circular shape, and when viewed along an axial direction of discharge electrode 1, two bar electrode parts 46 are positioned inside opening 43, and discharge electrode 1 is positioned between two bar electrode parts 46. Shortest distances between two bar electrode parts 46 and distal end portion 13 of discharge electrode 1 are identical to each other. The wording of identical used herein is not limited to strictly identical, but includes

generally identical.

[0065]

The discharge device of the present exemplary embodiment can stably produce leader discharge by dielectric breakdown between a portion closest to
5 distal end portion 13 of discharge electrode 1 among bar electrode parts 46 of opposite electrode 4, and distal end portion 13 of discharge electrode 1.

[0066]

(Sixth exemplary embodiment)

A discharge device of a sixth exemplary embodiment will be described
10 with reference to FIG. 6B. Note that detailed descriptions of components similar to components described in the second exemplary embodiment will be omitted.

[0067]

In the discharge device of the present exemplary embodiment, as a unit
15 for stably producing leader discharge, needle-shaped electrode part 41 is not provided, but opening 43 of opposite electrode 4 with an opening edge having a polygonal shape (quadrangle) is provided. When viewed along an axial direction of discharge electrode 1, discharge electrode 1 is positioned at a center of opening 43. An inner circumferential surface of opening 43 includes
20 a plurality of (four) flat surfaces that continue in a circumferential direction. Shortest distances between respective flat surfaces and distal end portion 13 of discharge electrode 1 are identical to each other.

[0068]

The discharge device of the present exemplary embodiment can stably
25 produce leader discharge between distal end portion 13 of discharge electrode 1, and a portion closest to distal end portion 13 of discharge electrode 1 among the respective flat surfaces constituting the inner circumferential surfaces of

opening 43.

[0069]

(Seventh exemplary embodiment)

5 A discharge device of a seventh exemplary embodiment will be described with reference to FIG. 6C. Note that detailed descriptions of components similar to components described in the second exemplary embodiment will be omitted.

[0070]

10 In the discharge device of the present exemplary embodiment, as a unit for stably producing leader discharge, needle-shaped electrode part 41 is not provided, but opening 43 of opposite electrode 4 with an opening edge having an elliptical shape is provided. When viewed along an axial direction of discharge electrode 1, discharge electrode 1 is positioned at a center of opening 43.

15 [0071]

The discharge device of the present exemplary embodiment can stably produce leader discharge between distal end portion 13 of discharge electrode 1, and two portions closest to distal end portion 13 of discharge electrode 1 in the inner peripheral surface of opening 43.

20 [0072]

(Eighth exemplary embodiment)

25 A discharge device of an eighth exemplary embodiment will be described with reference to FIGS. 7 to 14. Note that detailed descriptions of components similar to components described in the second and third exemplary embodiments will be omitted.

[0073]

As shown in FIGS. 7 to 9, the discharge device of the present

exemplary embodiment includes discharge electrode 1, voltage application unit 2, liquid supply unit 3 (cooler 30), opposite electrode 4, and current-carrying path 5, and further includes limiting resistor 6. Discharge electrode 1 and opposite electrode 4 are held at predetermined positions and postures by housing 80. As in the third exemplary embodiment, limiting resistor 6 is disposed at a midpoint of first current-carrying path 51 electrically connecting voltage application unit 2 to opposite electrode 4.

[0074]

Cooler 30 constituting liquid supply unit 3 is a heat exchanger including one pair of Peltier devices 301 and one pair of heat dissipation plates 302 connected one-to-one to the one pair of Peltier devices 301, the heat exchanger being configured to cool discharge electrode 1 by causing currents to pass through the one pair of Peltier devices 301. Part of each heat dissipation plate 302 is embedded in housing 80 made of a synthetic resin. A portion connected to Peltier device 301 and a peripheral portion of the portion in each heat dissipation plate 302 are exposed to enable heat dissipation.

[0075]

A cooling side of each of the one pair of Peltier devices 301 is mechanically and electrically connected to proximal end portion 15 of discharge electrode 1 via solder. A heat dissipation side of each of the one pair of Peltier devices 301 is mechanically and electrically connected to heat dissipation plate 302 corresponding one-to-one via solder. Causing currents to pass through the one pair of Peltier devices 301 is performed through the one pair of heat dissipation plates 302 and discharge electrode 1.

[0076]

Opposite electrode 4 includes supporting electrode part 42 having a plate shape and held in a posture orthogonal to the axial direction of discharge

electrode 1, and four needle-shaped electrode parts 41 supported by supporting electrode part 42 so as to be positioned more closely to discharge electrode 1 than supporting electrode part 42. The wording of orthogonal used herein is not limited to strictly orthogonal, but includes generally orthogonal.

5 [0077]

Each needle-shaped electrode part 41 is a slender piece-shaped electrode part, and has acute distal end portion 413 on one side of a longitudinal direction of the electrode part, and proximal end portion 415 on the other side of the longitudinal direction (opposite side of distal end portion 10 413). Each needle-shaped electrode part 41 is formed so as to extend from a peripheral portion of opening 43 having a circular shape included in opposite electrode 4 toward a center of opening 43. Four needle-shaped electrode parts 41 extend in directions approaching each other from four portions separated at regular intervals in a circumferential direction in the peripheral portion of 15 opening 43. The wording of regular intervals used herein is not limited to strictly regular intervals, but includes generally regular intervals.

[0078]

As shown in FIG. 8, when viewed along the axial direction of discharge electrode 1, distal end portions 413 of respective needle-shaped electrode parts 20 41 are positioned on an identical circle centered on discharge electrode 1, and equally spaced from each other in a circumferential direction of the identical circle.

[0079]

As shown in FIGS. 7 and 9, each needle-shaped electrode part 41 is 25 held in a posture slightly inclined from a posture parallel to supporting electrode part 42 (posture orthogonal to the axial direction of discharge electrode 1). This inclination is an inclination in a direction in which distal

end portion 413 of each needle-shaped electrode part 41 is brought close to discharge electrode 1. In the axial direction of discharge electrode 1, distance D1 between distal end portion 413 and discharge electrode 1 is smaller than distance D2 between proximal end portion 415 and discharge electrode 1.

5 [0080]

Setting the posture of each needle-shaped electrode part 41 in this way brings about an advantage that electric field concentration easily occurs at distal end portion 413 of each needle-shaped electrode part 41, and as a result, leader discharge easily occurs stably between distal end portion 413 of each
10 needle-shaped electrode part 41 and distal end portion 13 of discharge electrode 1.

[0081]

Furthermore, opposite electrode 4 includes step portion 45 that lies between supporting electrode part 42 and proximal end portion 415 of each
15 needle-shaped electrode part 41. Step portion 45 constitutes the peripheral portion of opening 43. Each needle-shaped electrode part 41 extends from step portion 45 toward a central portion of opening 43. Since step portion 45 lies between supporting electrode part 42 and each needle-shaped electrode part 41, in the axial direction of discharge electrode 1, distance D2 between
20 proximal end portion 415 and discharge electrode 1 is larger than distance D3 between supporting electrode part 42 and discharge electrode 1.

[0082]

Opposite electrode 4 including step portion 45 suppresses distal end portion 413 of needle-shaped electrode part 41 from protruding greatly. This
25 reduces a risk of, when opposite electrode 4 is placed on some plane during conveyance or assembly, distal end portion 413 being touched and pressed on the plane to deform needle-shaped electrode part 41.

[0083]

Furthermore, each needle-shaped electrode part 41 is provided with groove part 417 having an external shape extending from proximal end portion 415 toward distal end portion 413. Groove part 417 is formed by part of
5 needle-shaped electrode part 41 being pressed and bent in a thickness direction of needle-shaped electrode part 41. Since each needle-shaped electrode part 41 includes groove part 417, geometrical moment of inertia is increased, thereby making it unlikely that deformation occurs and increasing flexural strength.

10 [0084]

The discharge device of the present exemplary embodiment described above includes four needle-shaped electrode parts 41, and intermittently forms a discharge path in which dielectric breakdown occurs between distal end portion 413 of each needle-shaped electrode part 41 and distal end portion 13
15 of discharge electrode 1, producing leader discharge. Leader discharge produced here occurs in an extensive area in three dimensions between discharge electrode 1 and opposite electrode 4, as compared with a case of only one needle-shaped electrode part 41. A charged corpuscle liquid generated by this leader discharge is efficiently released outside through opening 43 along a
20 direction of an electric field formed between four needle-shaped electrode parts 41 and discharge electrode 1.

[0085]

In addition, in the discharge device of the present exemplary embodiment, distal end portions 413 of four needle-shaped electrode parts 41
25 are positioned on an identical circle and are equally spaced from each other in a circumferential direction of the identical circle. Therefore, the generated charged corpuscle liquid is more efficiently released outside through opening

43.

[0086]

Note that a number of needle-shaped electrode parts 41 is not limited to four, but at least a plurality of needle-shaped electrode parts 41 is required.

5 However, in order to release the charged corpuscle liquid outside efficiently, three or more needle-shaped electrode parts 41 are preferred.

[0087]

FIGS. 10A and 10B each show a modified example. The modified example shown in FIG. 10A is a modified example in which opposite electrode
10 4 includes three needle-shaped electrode parts 41. The modified example shown in FIG. 10B is a modified example in which opposite electrode 4 includes eight needle-shaped electrode parts 41. In these modified examples, groove part 417 and step portion 45 are omitted.

[0088]

15 In opposite electrode 4 in which three or more needle-shaped electrode parts 41 are disposed in opening 43, when viewed along the axial direction of discharge electrode 1, an opening area of opening 43 is preferably set more greatly than a total area of three or more needle-shaped electrode parts 41. When the opening area is set in this way, the electric field is easily
20 concentrated at distal end portion 413 of each needle-shaped electrode part 41, and leader discharge easily occurs stably.

[0089]

Incidentally, when opposite electrode 4 includes a plurality of needle-shaped electrode parts 41 as in the discharge device of the present exemplary
25 embodiment, intensity of electric field concentration at distal end portion 413 of each needle-shaped electrode part 41 is preferably uniform as much as possible. If the intensity of electric field concentration shows large variation,

it will be difficult for the charged corpuscle liquid to be released efficiently through opening 43.

[0090]

FIG. 11 shows a modified example in which point 4135 of distal end
5 portion 413 of each needle-shaped electrode part 41 is rounded. Point 4135 is a corner positioned at the most front end of each needle-shaped electrode part 41 when each needle-shaped electrode part 41 is viewed from a thickness direction thereof. Distal end portion 413 of each needle-shaped electrode part 41 having a rounded shape relieves electric field concentration to some extent.
10 This suppresses generation of large variation in intensity of electric field concentration caused by manufacturing variation during formation of each needle-shaped electrode part 41.

[0091]

FIGS. 12A and 12B show a modified example in which edge portion
15 4137 of distal end portion 413 of each needle-shaped electrode part 41 is chamfered. Edge portion 4137 is an edge portion close to discharge electrode 1 among edge portions of both sides of a thickness direction T1 of distal end portion 413 (refer to FIG. 12B). Edge portion 4137 of each needle-shaped electrode part 41 being chamfered relieves electric field concentration to some
20 extent. This suppresses generation of large variation in intensity of electric field concentration caused by manufacturing variation during formation of each needle-shaped electrode part 41.

[0092]

FIG. 13 shows main parts of mold device 9 that chamfers edge portion
25 4137 of each needle-shaped electrode part 41. Mold device 9 includes upper mold 91 and lower mold 92 for bending. When bending each needle-shaped electrode part 41 between upper mold 91 and lower mold 92, mold device 9

crushes edge portion 4137 of each needle-shaped electrode part 41 collectively on one flat surface 93 provided closer to a lower mold 92 to perform chamfering. When bending each needle-shaped electrode part 41, mold device 9 can chamfer edge portion 4137 at the same time. In addition, this brings about an advantage that when each needle-shaped electrode part 41 is chamfered, positions of distal end portions 413 of needle-shaped electrode parts 41 (positions of edge portions 4137) are aligned, and as a result, distances between distal end portions 413 of needle-shaped electrode parts 41 and discharge electrode 1 are made uniform.

10 [0093]

These modified examples have a tendency to relieve electric field concentration at distal end portion 413 of each needle-shaped electrode part 41, to suppress variation in intensity of electric field concentration, but also to hinder relieved electric field concentration from developing into leader discharge. However, as described above, by setting the opening area of opening 43 larger than the total area of the plurality of needle-shaped electrode parts 41, development into leader discharge is promoted stably.

[0094]

FIG. 14 shows a modified example in which needle-shaped electrode parts 41 and supporting electrode part 42 included in opposite electrode 4 are formed from materials different from each other. In this modified example, needle-shaped electrode parts 41 exposed to leader discharge can be formed from a material tolerant to discharge, such as titanium and tungsten, whereas supporting electrode part 42 can be formed from a material less tolerant to discharge than needle-shaped electrode parts 41, such as stainless steel. This modified example has an advantage that tolerance of opposite electrode 4 to leader discharge can be enhanced with an inexpensive structure.

[0095]

(Ninth exemplary embodiment)

A discharge device of a ninth exemplary embodiment will be described with reference to FIGS. 15A to 19. Note that detailed descriptions of components similar to components described in the eighth exemplary embodiment will be omitted.

[0096]

As shown in FIG. 15A, limiting resistor 6 included in the discharge device of the present exemplary embodiment is resistor 60 for a high voltage formed using a dedicated element. Resistor 60 includes resistance element 601, a pair of lead wires 602 connected to resistance element 601 electrically and mechanically, and terminals 603 connected to ends of lead wires 602 electrically and mechanically. In resistor 60 for the high voltage, each lead wire 602 generally includes a single wire and has a characteristic of being vulnerable to bending (in particular, vulnerable to repeated bending). To reduce the vulnerability, each lead wire 602 is covered with flexible cover 605 that can inhibit bending. Lead wire 602 covered with cover 605, which maintains a large curvature radius when bent, relieves stress concentration caused by the bending.

[0097]

As shown in FIGS. 15A and 15B, the discharge device of the present exemplary embodiment further includes fixing stand 81 for fixing resistor 60. Fixing stand 81 is integrally installed in housing 80 supporting discharge electrode 1 and opposite electrode 4.

[0098]

Resistance element 601 and terminals 603 are fixed to fixing stand 81 at respective predetermined positions. Accordingly, each lead wire 602 is held

at the predetermined position of fixing stand 81, and a risk of each lead wire 602 being bent repeatedly is suppressed. Peripheral wall 811 rises from a peripheral portion of fixing stand 81. Peripheral wall 811 is positioned to surround at least resistance element 601 and the one pair of lead wires 602 of resistor 60.

[0099]

As shown in FIG. 15B, it is possible to detachably put lid 82 on fixing stand 81. Resistance element 601 and the one pair of lead wires 602 are covered with peripheral wall 811 and lid 82 to prevent touch from outside.

[0100]

FIGS. 16 and 17 each show a modified example in which resistor 60 is installed without fixing stand 81 as shown in FIGS. 15A and 15B. In the modified example of FIG. 16, one lead wire 602 of resistor 60 is directly connected to opposite electrode 4 electrically and mechanically.

[0101]

In the modified example of FIG. 17, resistor 60 is directly connected to opposite electrode 4 electrically and mechanically, and furthermore, resistor 60 is fixed to an external surface of housing 80. In this modified example, a portion on a back side of housing 80 (opposite side of a side on which opposite electrode 4 is positioned) serves as fixing stand 81.

[0102]

The modified examples of FIGS. 16 and 17 are examples in which limiting resistor 6 is directly attached to opposite electrode 4, in other words, examples in which a length of the wire between opposite electrode 4 and limiting resistor 6 is set at 0 mm. When limiting resistor 6 is disposed in first current-carrying path 51, the length of the wire between opposite electrode 4 and limiting resistor 6 is preferably set in a range from 0 mm to 30 mm. This

is because when an instantaneous current flows through a discharge path in which dielectric breakdown occurs, current resistance becomes very small, and when the length of the wire between opposite electrode 4 and limiting resistor 6 exceeds 30 mm, discharge becomes unstable under influence of stray capacitance of the wire.

[0103]

A measurement result shown in a graph of FIG. 18A also shows that when the length of the wire between opposite electrode 4 and limiting resistor 6 exceeds 30 mm, an amount of active components (radical amount) generated by leader discharge drops. Although numerical values are not shown on a vertical axis of FIG. 18A, an upper limit of generated radical amount is about 5 trillion pieces/sec.

[0104]

Also, when limiting resistor 6 is disposed in first current-carrying path 51, a length in first current-carrying path 51 between voltage application unit 2 and limiting resistor 6 is preferably set in a range from 0 mm to 200 mm. This is because when an instantaneous current flows, current resistance becomes very small, and when the length of the wire between voltage application unit 2 and limiting resistor 6 exceeds 200 mm, discharge becomes unstable under influence of stray capacitance of the wire.

[0105]

A measurement result shown in a graph of FIG. 18B also shows that when the length of the wire between voltage application unit 2 and limiting resistor 6 exceeds 200 mm, an amount of effective components (radical amount) generated by leader discharge drops. Also in FIG. 18B, the upper limit of generated radical amount is about 5 trillion pieces/sec.

[0106]

The measurement results shown in the graphs of FIGS. 18A and 18B are results measured using a device schematically shown in FIG. 19. In this device, limiting resistor 6 is disposed in a wire electrically connecting opposite electrode 4 to voltage application unit 2, metal plate 89 serving as ground is
5 disposed at a place separated from limiting resistor 6 by distance D4 (= 4 mm), a high voltage of 7.0 kV is applied between metal plate 89 and a discharge electrode that is not shown, and the radical amount generated by leader discharge is measured.

[0107]

10 The above results are results obtained when limiting resistor 6 is disposed in first current-carrying path 51, but a similar result is obtained when limiting resistor 6 is disposed in second current-carrying path 52 electrically connecting discharge electrode 1 to voltage application unit 2 (refer to FIG. 4B).

15 [0108]

That is, when limiting resistor 6 is disposed in second current-carrying path 52, a length of second current-carrying path 52 between discharge electrode 1 and limiting resistor 6 is preferably set within 30 mm in order to produce leader discharge stably. Also, a length of second current-carrying
20 path 52 between voltage application unit 2 and limiting resistor 6 is preferably set within 200 mm in order to produce leader discharge stably.

[0109]

(Tenth exemplary embodiment)

A discharge device of a tenth exemplary embodiment will be described
25 with reference to FIGS. 20 to 22. Note that detailed descriptions of components similar to components described in the eighth exemplary embodiment will be omitted.

[0110]

FIG. 20 is a plan view showing main parts of the discharge device of the present exemplary embodiment. FIG. 21 is a cross-sectional view taken along line 21-21 of FIG. 20, and FIG. 22 is a cross-sectional view taken along
5 line 22-22 of FIG. 20.

[0111]

In FIG. 20, discharge electrode 1, opposite electrode 4, one pair of Peltier devices 301, and other components are omitted. In the discharge device of the present exemplary embodiment, in an exposed portion of each
10 heat dissipation plate 302 (portion that is not buried in housing 80), in a peripheral area of portion 3025 in which Peltier device 301 is mounted, a corner portion is chamfered. Specifically, portions shown by arrows C in FIGS. 20 to 22 are chamfered. Portion 3025 having a stage shape on which Peltier device 301 is mounted is not chamfered.

15 [0112]

Each heat dissipation plate 302 is chamfered, when each heat dissipation plate 302 is dipped into a coating agent such as a resin (for example, ultraviolet cured urethane resin) to perform coating, in order to cause this coating to cover the corner portion of each heat dissipation plate 302 more
20 securely. This is because each heat dissipation plate 302 is manufactured by cutting a sheet metal with a mold, and thus a generally right-angled corner portion is formed in an edge of the sheet metal after the cutting. If each heat dissipation plate 302 has the generally right-angled corner portion, coating is unlikely to be formed with a sufficient film thickness in the corner portion, and
25 the corner portion of each heat dissipation plate 302 is easily exposed.

[0113]

Since the discharge device of the present exemplary embodiment

produces leader discharge with higher energy than corona discharge, there is a tendency for acidity of liquid 35 supplied to discharge electrode 1 (dew condensation water) to be further strengthened. Therefore, if a portion of each heat dissipation plate 302 is exposed from the coating, the portion is
5 oxidized (corroded) and durability drops.

[0114]

As another countermeasure for this problem, a countermeasure to suppress exposure by setting a large film thickness of the coating on the whole is also considered. However, the coating is performed so as to cover an overall
10 portion including heat dissipation plates 302 and Peltier devices 301 mounted on heat dissipation plates 302 from a cooling side to a heat dissipation side. Therefore, when the film thickness of the coating becomes large on the whole, cooling performance of Peltier devices 301 drops. The discharge device of the present exemplary embodiment can inhibit deterioration of each heat
15 dissipation plate 302 and solder, while suppressing the film thickness of the coating.

[0115]

(Eleventh exemplary embodiment)

A discharge device of an eleventh exemplary embodiment will be
20 described with reference to FIGS. 23 and 24. Note that detailed descriptions of components similar to components described in the eighth exemplary embodiment will be omitted.

[0116]

In the discharge device of the present exemplary embodiment, in order
25 to adjust a discharge frequency in leader discharge (how often an instantaneous current flows), a capacitor is not disposed on a high-voltage side like the discharge device of the fourth exemplary embodiment, but feedback

time controller 85 is disposed on a low-voltage side.

[0117]

FIG. 23 is a block diagram showing main parts of the discharge device of the present exemplary embodiment. As shown in FIG. 23, in addition to high voltage generating circuit 20 constituting voltage application unit 2, the discharge device of the present exemplary embodiment includes voltage controller 83, current controller 84, feedback time controller 85, high-voltage drive circuit 86, and input unit 87.

[0118]

When power is supplied to input unit 87, high-voltage drive circuit 86 operates and a high voltage is output from high-voltage generating circuit 20. When a control signal regarding this output is input into voltage controller 83 and current controller 84, voltage controller 83 and current controller 84 generate a control signal for controlling a voltage and a current to be predetermined values via feedback time controller 85. Based on this control signal, high-voltage drive circuit 86 repeats work of raising an output voltage to a predetermined discharge voltage, and when discharge accompanied by dielectric breakdown occurs and the output voltage drops, raising the output voltage again to the predetermined discharge voltage. This produces leader discharge.

[0119]

In the discharge device of the present exemplary embodiment, feedback time controller 85 can control feedback time from drop of the output voltage to returning to the predetermined discharge voltage again. The discharge frequency of leader discharge is adjusted by controlling the feedback time.

[0120]

FIG. 24 shows a modified example of the discharge device of the

present exemplary embodiment. In this modified example, high-voltage drive circuit 86 includes microcomputer 861 and peripheral circuit unit 862, and microcomputer 861 constitutes feedback time controller 85. Furthermore, a configuration is also possible in which microcomputer 861 serves as at least one of voltage controller 83 and current controller 84.

[0121]

The discharge device of the present exemplary embodiment has an advantage that feedback time controller 85 disposed on a low-voltage side can adjust the discharge frequency of leader discharge, leading to a wide adjustable range of discharge characteristics, and an advantage that an increase in high-voltage side members is suppressed, resulting in cost reduction.

INDUSTRIAL APPLICABILITY

[0122]

As described above, the discharge device according to the present invention can generate active components by leader discharge and suppress an increase in ozone, allowing application to various uses such as refrigerators, washing machines, driers, air conditioners, fans, air cleaners, humidifiers, facial beautifiers, and automobiles.

REFERENCE MARKS IN THE DRAWINGS

[0123]

1: discharge electrode

13: distal end portion

15: proximal end portion

2: voltage application unit

	3: liquid supply unit
	35: liquid
	4: opposite electrode
	41: needle-shaped electrode part
5	410: protruding surface
	413: distal end portion
	415: proximal end portion
	417: groove part
	42: supporting electrode part
10	420: opposite surface
	43: opening
	45: step portion
	5: current-carrying path
	51: first current-carrying path
15	52: second current-carrying path
	6: limiting resistor
	7: capacitor
	9: mold device
	91: upper mold
20	92: lower mold
	9: mold device
	93: one surface
	T1: thickness direction
	D1: distance between distal end portion of needle-shaped electrode part
25	and discharge electrode
	D2: distance between proximal end portion of needle-shaped electrode
	part and discharge electrode

D3: distance between supporting electrode part and discharge electrode

CLAIMS

1. A discharge device comprising:
a discharge electrode;
5 a voltage application unit that applies a voltage to the discharge electrode to produce discharge that has further developed from corona discharge in the discharge electrode;
an opposite electrode positioned facing the discharge electrode,
wherein the discharge electrode is configured to receive higher energy
10 than corona discharge to produce a discharge path in which dielectric breakdown occurs so as to extend around from the discharge electrode,
wherein the discharge electrode is configured to produce the discharge path in which dielectric breakdown occurs to connect between the discharge electrode and the opposite electrode, and
15 wherein the opposite electrode includes a needle-shaped electrode part facing the discharge electrode.

2. The discharge device according to claim 1, further comprising a liquid supply unit that supplies liquid to the discharge electrode, wherein the
20 liquid supplied to the discharge electrode is electrostatically atomized by the discharge.

3. The discharge device according to claim 1, wherein
25 the needle-shaped electrode part includes a distal end portion and a proximal end portion on opposite sides,
the discharge electrode has an axial direction, and

a distance between the distal end portion and the discharge electrode in the axial direction is smaller than a distance between the proximal end portion and the discharge electrode in the axial direction.

- 5 4. The discharge device according to claim 3, wherein
the opposite electrode includes:

a supporting electrode part held in a posture orthogonal to the axial direction; and

- 10 a step portion that lies between the supporting electrode part
and the needle-shaped electrode part, and

a distance between the proximal end portion and the discharge electrode in the axial direction is larger than a distance between the supporting electrode part and the discharge electrode in the axial direction.

- 15 5. The discharge device according to any one of claims 1 to 4, wherein
the needle-shaped electrode part includes a groove part for inhibiting deformation of the needle-shaped electrode part, and

the groove part is formed by a portion of the needle-shaped electrode part bending in a thickness direction of the needle-shaped electrode part.

20

6. The discharge device according to claim 1, wherein
the opposite electrode further includes a supporting electrode part that supports the needle-shaped electrode part, and

- 25 the needle-shaped electrode part and the supporting electrode part are
members of materials different from each other.

7. The discharge device according to any one of claims 1 to 6, wherein

the opposite electrode includes a plurality of the needle-shaped electrode parts.

8. The discharge device according to claim 7, wherein the distal end
portion of each of the plurality of needle-shaped electrode parts is positioned
5 on an identical circle.

9. The discharge device according to claim 8, wherein the distal end
portion of each of the plurality of needle-shaped electrode parts is equally
spaced from each other in a circumferential direction of the identical circle.

10

10. The discharge device according to any one of claims 7 to 9,
wherein each of the plurality of needle-shaped electrode parts includes a distal
end portion having a rounded shape.

15 11. The discharge device according to any one of claims 7 to 10,
wherein

each of the plurality of needle-shaped electrode parts is a piece-shaped
electrode part having a thickness, and

in an edge portion of a thickness direction of each of the plurality of
20 needle-shaped electrode parts, a portion close to the discharge electrode is
chamfered.

12. The discharge device according to any one of claims 7 to 11,
wherein the plurality of needle-shaped electrode parts is three or more needle-
25 shaped electrode parts spaced from each other.

13. The discharge device according to claim 12, wherein

the opposite electrode further includes an opening in which the three or more needle-shaped electrode parts are disposed, and

an opening area of the opening is larger than a total area of the three or more needle-shaped electrode parts.

5

14. A discharge device comprising:

a discharge electrode;

a voltage application unit that applies a voltage to the discharge electrode to produce discharge that has further developed from corona

10 discharge in the discharge electrode;

an opposite electrode positioned facing the discharge electrode,

wherein the discharge electrode is configured to produce a discharge path in which dielectric breakdown occurs so as to extend around from the discharge electrode,

wherein the discharge electrode is configured to produce the discharge path in which dielectric breakdown occurs to connect between the discharge electrode and the opposite electrode, and
, wherein

5 the opposite electrode includes:

 at least one acute protruding surface facing the discharge electrode; and

 an opposite surface facing the discharge electrode, and

 the opposite surface has a flat surface, a concave surface, or a shape in
10 which the flat surface and the concave surface are combined.

15 15. The discharge device according to any one of claims 1 to 14, further comprising a capacitor that is electrically connected in parallel to the voltage application unit.

15

 16. A method for manufacturing the discharge device according to claim 11, the method comprising crushing the edge portion of the thickness direction of each of the plurality of needle-shaped electrode parts at one time on one surface of a mold device to perform the chamfering.

20