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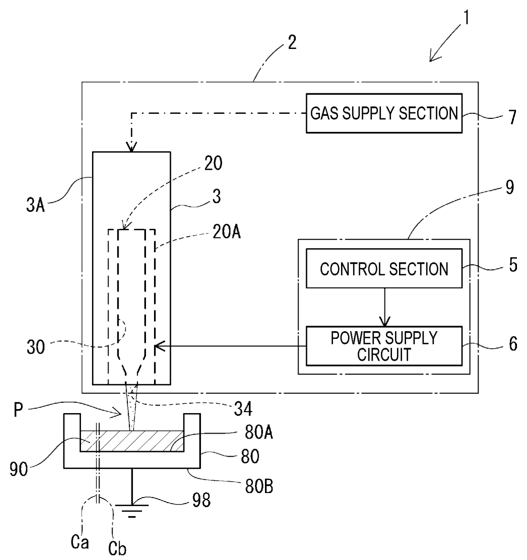
(54) SOLUTION TREATMENT DEVICE AND SOLUTION TREATMENT METHOD

(57) A solution processing apparatus (1) includes a main body portion (20A) having a gas flow channel (30) through which a gas flows, an electric discharge section (40) for generating plasma discharge within the gas flow channel (30), and a power supply section (9) for applying voltage between a first electrode (42) and the second electrode (44) of the electric discharge section (40). The power supply section (9) periodically applying AC voltage between the first electrode (42) and the second electrode (44), thereby causing the electric discharge section (40) to perform a discharge operation in such a manner that current flowing through a solution (90) has a waveform composed of waveforms which are alternately repeated and represent positive current values and negative current values, respectively, the average of the current values becomes substantially 0 in each period, and the absolute value of a positive peak current value becomes larger than the absolute value of a negative peak current value in each period.

FIG. 1



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Description

TECHNICAL FIELD

[0001] The present disclosure relates to a solution processing apparatus for processing a solution containing proteins derived from blood and a solution processing method therefor.

BACKGROUND ART

[0002] Patent Literature 1 discloses a method for processing an aqueous protein solution. In the processing method disclosed in Patent Literature 1, an aqueous protein solution is prepared by mixing proteins into an aqueous solvent, and plasma generated by a plasma generation apparatus is applied to the aqueous protein solution, whereby a protein film is manufactured.

CITATION LIST

PATENT LITERATURE

[0003] Patent Literature 1: JP2015-218245A

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0004] In the processing method disclosed in Patent Literature 1, AC voltage from a commercial AC power supply; namely, general AC voltage, such as sinusoidal AC voltage, is stepped up, and the stepped-up voltage is applied between electrodes, thereby generating plasma. However, the method disclosed in Patent Literature 1 has the following problem. When plasma is applied to a common protein solution, charge transfer between charged particles occurs unevenly during irradiation with plasma, and the charged particles diffuse, in the form of current, to a deep portion of the solution or in a substance in contact with the solution, whereby the current is converted to thermal energy. In such a case, proteins may possibly be denatured. Also, this method is problematic in that, when a surface side portion of the solution is to be selectively coagulated, loss of energy is likely to occur due to flow of current to the deep portion of the solution.

[0005] Furthermore, in the processing method disclosed in Patent Literature 1, charging features of proteins and plasma are not taken into consideration, and aggregation of protein particles may be hindered when the polarity of the proteins is the same as the polarity of the plasma. Particular, in a protein solution containing blood components; namely, untreated human blood or serum containing proteins, which include red blood cells, hemoglobin, and albumin in large amounts, the proteins are negatively charged. Thus, efficient formation of an aggregated film composed of a predominant amount of negatively charged proteins may be hindered.

[0006] An object of the present disclosure is to provide a technique which at least partially solves the above-described problems. The technique can aggregate proteins in a solution containing proteins derived from blood and easily suppress excessive flow of current to a deep portion of the solution.

SOLUTION TO PROBLEM

[0007] A solution processing apparatus of one mode of the present disclosure is a solution processing apparatus which applies plasma to a solution containing proteins derived from blood. The solution processing apparatus comprises:

a main body portion having a gas flow channel which has a discharge opening for gas and through which the gas flows toward the discharge opening;
an electric discharge section which includes a dielectric layer, and a first electrode and a second electrode disposed to face each other with the dielectric layer intervening therebetween and which generates plasma discharge within the gas flow channel; and
a power supply section for applying voltage between the first electrode and the second electrode,
wherein the power supply section periodically applies AC voltage between the first electrode and the second electrode, thereby causing the electric discharge section to perform a discharge operation in such a manner that, in a waveform representing values of current flowing through the solution, a waveform representing positive current values and a waveform representing negative current values are alternately repeated, the average of the current values becomes substantially 0 in each period, and the absolute value of a positive peak current value becomes larger than the absolute value of a negative peak current value in each period.

[0008] In the above-described solution processing apparatus, proteins derived from blood (hereinafter also referred to as blood proteins) can be aggregated in the solution by applying charged plasma to the solution such that current flows through the solution. In addition, the power supply section causes the electric discharge section to perform a discharge operation in such a manner that, in each period, the absolute value of the positive peak current value becomes greater than the absolute value of the negative peak current value. Namely, in the case where current flows through the solution in the positive direction due to positively charged particles, since the current has a relatively large peak current value and changes sharply, negatively charged blood proteins can be efficiently aggregated in the solution. This effect becomes more remarkable, for example, in the case of a solution in which the amount of negatively charged blood proteins is greater than the amount of positively charged blood proteins.

[0009] However, in the case where the charge provided to the solution by plasma irradiation is excessively biased to the positive side or the negative side, the current becomes more likely to flow to a deep portion of the solution. This is undesirable in the case where electrification of the deep portion must be suppressed. In view of this, the above-described solution processing apparatus supplies current to the solution in such a manner that the average of current values becomes substantially 0 in each period. As a result of such an operation, excessive flow of current to the deep portion of the solution can be suppressed.

[0010] In the present specification, "the average of current values becomes substantially 0 in each period" means that, in each period, the absolute value of the average of current values is 1/10 or less of the effective value of the current. For example, when the average of current values is substantially 0 in a certain first period, it means that the absolute value of the average of current values in that first period is 1/10 or less of the effective value of the current in that first period. Similarly, when the average of current values is substantially 0 in a second period different from the first period, it means that the absolute value of the average of current values in that second period is 1/10 or less of the effective value of the current in that second period.

[0011] In the solution processing apparatus of the one mode of the present disclosure, the above-described gas may be a rare gas. This solution processing apparatus becomes able to efficiently cause ionization by using the rare gas, and can perform plasma irradiation satisfactorily.

[0012] In the solution processing apparatus of the one mode of the present disclosure, the above-described gas may be helium gas. This solution processing apparatus becomes able to more efficiently cause ionization by using helium, and can perform plasma irradiation more satisfactorily.

[0013] In the solution processing apparatus of the one mode of the present disclosure, the electric discharge section may be configured such that one of the first electrode and the second electrode faces a space within the gas flow channel directly or with another member intervening therebetween, and creeping discharge is generated within the gas flow channel as a result of application of the voltage between the first electrode and the second electrode. In this solution processing apparatus, since the electric discharge section is configured to generate creeping discharge, plasma can be applied more efficiently by using a lower application voltage.

[0014] The solution processing apparatus of the one mode of the present disclosure may further comprise a container which contains the solution. This solution processing apparatus can cause aggregation of proteins derived from blood in the solution contained in the container.

[0015] In the solution processing apparatus of the one mode of the present disclosure, the container may have electrical conductivity and be electrically connected to a ground portion. In this solution processing apparatus, when plasma is applied to the solution contained in the container, current flows more easily to the ground portion side through the container.

[0016] In the solution processing apparatus of the one mode of the present disclosure, the container may be formed of electrically conductive glass. This solution processing apparatus can secure some resistance at the container and can control the current flowing to the ground portion side through the container.

[0017] A solution processing method, which is one mode of the present disclosure is a solution processing method for processing a solution containing proteins derived from blood by using a solution processing apparatus comprising a main body portion having a gas flow channel which has a discharge opening for gas and through which the gas flows toward the discharge opening, an electric discharge section which includes a dielectric layer and a first electrode and a second electrode disposed to face each other with the dielectric layer intervening therebetween and which generates plasma discharge within the gas flow channel; and a power supply section for applying voltage between the first electrode and the second electrode,

> wherein the solution processing method comprises an irradiation step of applying plasma to the solution by the solution processing apparatus, and
> wherein, in the irradiation step, the power supply section periodically applies AC voltage between the first electrode and the second electrode, thereby causing the electric discharge section to perform a discharge operation in such a manner that, in a waveform representing values of current flowing through the solution, a waveform representing positive current values and a waveform representing negative current values are alternately repeated, the average of the current values becomes substantially 0 in each period, and the absolute value of a positive peak current value becomes larger than the absolute value of a negative peak current value in each period.

[0018] In the above-described solution processing method, blood proteins can be aggregated in the solution by applying charged plasma to the solution such that current flows through the solution. In addition, the power supply section causes the electric discharge section to perform a discharge operation in such a manner that, in each period, the absolute value of the positive peak current value becomes greater than the absolute value of the negative peak current value. Namely, in the case where current flows through the solution in the positive direction due to positively charged particles, since the current has a relatively large peak current value and changes sharply, negatively charged blood proteins can be efficiently aggregated in the solution. This effect becomes more remarkable, for example, in the case of a solution in which the amount of negatively charged blood proteins is greater than the amount of positively charged blood proteins.

[0019] However, in the case where the charge provided to the solution by plasma irradiation is excessively biased to the positive side or the negative side, the current becomes more likely to flow to a deep portion of the solution. This is undesirable in the case where electrification of the deep portion must be suppressed. In view of this, the above-described solution processing apparatus supplies current to the solution in such a manner that the average of current values becomes substantially 0 in each period. As a result of such an operation, excessive flow of current to the deep portion of the solution can be suppressed.

ADVANTAGEOUS EFFECT OF INVENTION

[0020] The technique according to the present disclosure can coagulate a blood protein-containing solution and easily suppresses excessive flow of current to a deep portion of the solution.

BRIEF DESCRIPTION OF DRAWINGS

[0021]

FIG. 1 is a schematic diagram schematically illustrating a solution processing apparatus of a first embodiment.

FIG. 2 is a perspective view conceptually illustrating a main body portion in the solution processing apparatus of the first embodiment.

FIG. 3 is an exploded perspective view in which the main body portion illustrated in FIG. 2 is shown in a state in which the main body portion is divided to three portions.

FIG. 4 is a schematic sectional view of the main body portion illustrated in FIG. 2, the sectional view showing a cross section taken, at a center position in a third direction (width direction), perpendicularly to the third direction.

FIG. 5 is a schematic sectional view of the main body portion illustrated in FIG. 2, the sectional view showing a cross section taken, at a center position in a first direction, perpendicularly to the first direction.

FIG. 6 is a schematic sectional view of the main body portion illustrated in FIG. 2, the sectional view showing a cross section taken, at a center position in a second direction (thickness direction) , perpendicularly to the second direction.

FIG. 7 is a waveform chart illustrating the waveform of voltage applied between a first electrode and a second electrode by a power supply section in the solution processing apparatus according to the first embodiment.

FIG. 8 is a waveform chart illustrating the waveform of leakage current which leaks from a container when plasma generated through application of voltage having a waveform as shown in FIG. 7 is applied to blood proteins within the container in the solution processing apparatus according to the first embodiment.

FIG. 9 is a schematic diagram schematically illustrating a solution processing apparatus of a second embodiment.

DESCRIPTION OF EMBODIMENTS

<First embodiment >

1. Configuration of solution processing apparatus

[0022] A solution processing apparatus 1 according to a first embodiment has a configuration as shown in FIG. 1. The solution processing apparatus 1 is an apparatus for applying plasma to a solution containing blood proteins and has a function of processing the solution containing blood proteins. The solution processing apparatus 1 mainly includes a plasma irradiation apparatus 2 and a container 80. The plasma irradiation apparatus 2 mainly includes an irradiation unit 3, a gas supply section 7, a control section 5, a power supply section 9, etc.

[0023] The container 80 is a container for containing a solution 90 containing blood proteins (hereinafter referred to as the "blood protein containing solution 90"). The container 80 has electrical conductivity and is electrically connected to a ground portion 98. The ground portion 98 is an electrically conductive portion whose potential is stably maintained at a potential near a predetermined ground potential (for example, 0 V). The ground portion 98 is formed of an electrically conductive material such as a metallic material. The container 80 has an inner surface portion 80A with which the solution 90 comes into contact, and the inner surface portion 80Ais electrically connected to the ground portion 98. Accordingly, when the potential of the inner surface portion 80A is higher than the potential of the ground portion 98, current flows from the inner surface portion 80A side to the ground portion 98 side. In contrast, when the potential of the inner surface portion 80A is lower than the potential of the ground portion 98, current flows from the ground portion 98 side to the inner surface portion 80A.

[0024] In a representative example shown in FIG. 1, the entirety of the container 80 is formed of resin. However, a portion of the container 80 may be formed of a material other than resin (for example, a known metallic material or a known non-metallic material). The container 80 has an outer surface portion 80B electrically connected to the inner surface portion 80A which comes into contact with the solution 90, and therefore, current can flow between the inner surface portion 80A and the outer surface portion 80B. The outer surface portion 80B of the container 80 is electrically connected to the ground portion 98, so that the outer surface portion 80B is maintained at the same potential as the ground portion 98. Accordingly, when the potential of the inner surface portion 80A is higher than the potential of the ground portion 98, current flows from the inner surface portion 80A side to the ground portion 98 side through the outer surface portion 80B.

[0025] The solution 90 is a liquid containing blood proteins. The solution 90 may be in the form of liquid, jelly, gel, or sol, or may contain solutions in two or more of these forms. Namely, the "solution" used in the present specification is a conceptual term which encompasses all of liquid, gel, and sol. Also, the solution 90 contains components of blood as blood proteins, for example, may be blood containing plasma, red blood cells, white blood cells, and platelets. However, the solution 90 may be one which does not contain some components such as white blood cells and platelets. Notably, the above-described "blood proteins" refer to proteins which are present in large amounts in blood and which are easily dissolved in water; specifically, they refer to negatively charged proteins such as albumin and hemoglobin and positively charged proteins such as immunoglobulin.

[0026] The gas supply section 7 is an apparatus for supplying an inert gas such as helium gas or argon gas (hereinafter also referred to simply as gas). The gas supply section 7 supplies the inert gas to a gas flow channel 30, which will be described later, through, for example, a flexible pipe passage present between the irradiation unit 3 and the gas supply section 7. The gas supply section 7 includes a regulator which reduces the pressure of a high-pressure gas supplied from, for example, a gas cylinder or the like, and a control section which performs flow rate control. This control section can control the flow rate of gas flowing through the gas flow channel 30. In FIG. 1, the above-described pipe passage, the above-described regulator, the above-described control section, etc. are not illustrated.

[0027] The power supply section 9 is an apparatus which generates a periodic voltage and applies the voltage between two electrodes (which will be described later) provided in the irradiation unit 3. The power supply section 9 mainly includes a control section 5 and a power supply circuit 6. Various well known power supply circuits may be employed as the power supply circuit 6 so long as the employed circuit can generate a high voltage having a high frequency and apply the voltage between conductor portions. The control section 5 may be any apparatus which can control the power supply circuit 6 and is composed of, for example, a controller having an information processing unit such as a microcomputer. In the example of FIG. 1, the entirety of the power supply section 9 is provided outside the irradiation unit 3. However, a portion or the entirety of the power supply section 9 may be provided in the irradiation unit 3. The power supply section 9 will be described in detail later.

[0028] The irradiation unit 3 is a unit which can generate plasma and discharge the plasma. The irradiation unit 3 mainly includes a plasma irradiation portion 20 and a holding portion 3A for holding the plasma irradiation portion 20. The irradiation unit 3 may be configured such that it is used while being grasped by a user or may be configured such that it can be moved by a means (for example, a robot or the like) other than the user. Alternatively, the irradiation unit 3 may be configured such that it is used at a fixed position; i.e., in an immobile state.

[0029] The holding portion 3A is a portion to which a main body portion 20A of the plasma irradiation portion 20 is fixed. The holding portion 3A has a function of holding the main body portion 20A. The holding portion 3A may be configured to hold the main body portion 20A disposed inside the holding portion 3A or may be configured to hold the main body portion 20A disposed outside the holding portion 3A. In the example of FIG. 1, the holding portion 3A is configured as a case, and the main body portion 20A is housed in the holding portion 3A and fixed to the holding portion 3A.

[0030] The plasma irradiation portion 20 is configured as an apparatus for producing dielectric barrier discharge. The plasma irradiation portion 20 has an external appearance as shown in FIG. 2 and includes the main body portion 20A having a predetermined three-dimensional shape. In the example of FIG. 2, the main body portion 20A is configured to have a plate-like shape and a rectangular parallelepiped shape. The plasma irradiation portion 20 operates to discharge plasma P from a discharge opening 34 formed at an end of the main body portion 20A in the longitudinal direction. The plasma P is so-called atmospheric cold plasma.

[0031] In FIG. 3, the structure of the main body portion 20A divided to three portions is conceptually shown as an exploded perspective view. The main body portion 20A includes a third dielectric layer 53 provided at a central portion in a thickness direction and a fourth dielectric layer 54 provided on one side of the third dielectric layer 53 in the thickness direction. Furthermore, the main body portion 20A includes a first dielectric layer 51 and a second dielectric layer 52 provided on the other side of the third dielectric layer 53 in the thickness direction. A first electrode 42 and a second electrode 44 are embedded in a dielectric region formed by the first dielectric layer 51 and the second dielectric layer 52. Although the triparted structure of the main body portion 20A is conceptually shown in FIG. 3, in the actual structure, the first dielectric layer 51, the second dielectric layer 52, the third dielectric layer 53, and the fourth dielectric layer 54 are formed as parts of an integral dielectric portion 50 (see FIG. 5).

[0032] As shown in FIG. 4, a gas flow channel 30 configured to allow flow of gas toward the discharge opening 34 is provided in the main body portion 20A. The gas flow channel 30 has an introduction opening 32 for introducing gas, the discharge opening 34 for discharging gas, and an intermediate flow channel 36 provided between the introduction opening 32 and the discharge opening 34. The introduction opening 32 is an opening which is provided on the rear end side of the main body portion 20A and communicates with an internal space of the main body portion 20A and an outside space. The discharge opening 34 is an opening which is provided on the forward end side of the main body portion 20A and communicates with the internal space of the main body portion 20Aand the outside space. The intermediate flow channel 36 is a gas flow passage which communicates with the introduction opening 32 and the discharge opening 34 and is a flow passage which allows flow of gas between the introduction opening 32 and the discharge opening 34. The gas flow channel 30 serves as a guide passage which introduces from the introduction opening 32 the inert gas supplied from the gas supply section 7 provided on the outside of the irradiation unit 3 and guides the gas introduced from the introduction opening 32 side to the discharge opening 34 through the space within the intermediate flow channel 36. In FIG. 4, a pipe passage 7A for introducing the inert gas supplied from the gas supply section 7 to the introduction opening 32 is imaginarily shown by two-dot chain lines.

[0033] As shown in FIG. 4, an electric discharge section 40 is provided in the plasma irradiation portion 20. The electric discharge section 40 is a portion for generating plasma discharge in the gas flow channel 30. The electric discharge section 40 includes the dielectric portion 50, the first electrode 42, and the second electrode 44. The first electrode 42 and the second electrode 44 are disposed to face each other, with the first dielectric layer 51 intervening therebetween, which is a portion of the dielectric portion 50. The electric discharge section 40, which is configured as a creeping discharge section, generates in the gas flow channel 30 an electric field based on the potential difference between the first electrode 42 and the second electrode 44 and generates cold atmospheric pressure plasma by creeping discharge along the inner wall surface of the gas flow channel 30.

[0034] In the present specification, the direction in which the gas flow channel 30 extends in the plasma irradiation portion 20 will be referred to as the first direction, of directions orthogonal to the first direction, the direction parallel to the thickness direction of the dielectric portion 50 will be referred to as the second direction, and the direction orthogonal to the first direction and the second direction will be referred to as the third direction. In the example of FIG. 4, the dielectric portion 50, the first electrode 42, and the second electrode 44 are integrally provided, whereby the main body portion 20A is constituted. The first direction is the longitudinal direction of the main body portion 20A. As shown in FIG. 5, the second direction is the lateral direction of the main body portion 20A in a cross section of the main body portion 20A taken along a plane orthogonal to the first direction. The second direction corresponds to the height direction and thickness direction of the main body portion 20A. The third direction is the longitudinal direction of the main body portion 20A in the cross section of the main body portion 20A taken along the plane orthogonal to the first direction. The third direction corresponds to the width direction of the main body portion 20A. In the present specification, a side in the first direction where the discharge opening 34 is present is the forward end side of the main body portion 20A, and a side in the first direction where the introduction opening 32 is present is the rear end side of the main body portion 20A.

[0035] As shown in FIG. 5, the dielectric portion 50 includes the first dielectric layer 51, the second dielectric layer 52, the third dielectric layer 53, and the fourth dielectric layer 54, and the main body portion 20A has a hollow structure as a whole. The first dielectric layer 51 is disposed on the other end side in the second direction (thickness direction) in relation to the space within the intermediate flow channel 36. The second electrode 44 is embedded in the first dielectric layer 51. Namely, the first electrode 42 and the second electrode 44 face each other with the first dielectric layer 51 intervening therebetween. The second dielectric layer 52 is a ceramic protection layer formed of a ceramic material to cover the first electrode 42. The second dielectric layer 52 is disposed to cover the first electrode 42 on the side toward the space of the intermediate flow channel 36 in relation to the first dielectric layer 51. The first dielectric layer 51 and the second dielectric layer 52 constitute an inner wall portion of the intermediate flow channel 36 located on the other side in the second direction. The fourth dielectric layer 54 is disposed on one side in the second direction (thickness direction) in relation to the space of the intermediate flow channel 36 and constitutes an inner wall portion of the intermediate flow channel 36 located on the one side in the second direction. The third dielectric layer 53 is disposed between the first dielectric layer 51 and the fourth dielectric layer 54 in the second direction and constitutes a side wall portion of the intermediate flow channel 36 located on one side in the third direction and a side wall portion of the intermediate flow channel 36 located on the other side in the third direction. Namely, the intermediate flow channel 36 is defined by the first dielectric layer 51, the second dielectric layer 52, the third dielectric layer 53, and the fourth dielectric layer 54. For example, a ceramic material such as alumina, a glass material, or a resin material can be appropriately used as the materials of the first dielectric layer 51, the second dielectric layer 52, the third dielectric layer 53, and the fourth dielectric layer 54. Use of alumina, which is high in mechanical strength, as a dielectric in the dielectric portion 50 facilitates miniaturization of the electric discharge section 40.

[0036] As shown in FIG. 5, the first electrode 42 faces the space within the intermediate flow channel 36, with the second dielectric layer 52 intervening therebetween, which is a portion of the dielectric portion 50. The second electrode 44 is provided on the side of the first electrode 42 opposite to the intermediate flow channel 36. The second electrode 44 is disposed in parallel to the first electrode 42 and is away from the intermediate flow channel 36 by a greater distance in the second direction than the first electrode 42. As shown in FIG. 6, the first electrode 42 extends straight in the first direction along the intermediate flow channel 36 and has a first width and a first thickness. The first electrode 42 is disposed in a first region in the first direction. The second electrode 44 extends straight in the first direction along the intermediate flow channel 36 and has a second width and a second thickness. The second electrode 44 is disposed in a second region in the first direction. No particular limitation is imposed on the thicknesses, widths, arrangements of the first electrode 42 and the second electrode 44. The widths and/or thicknesses of the first electrode 42 and the second electrode 44 may be the same or differ from each other.

[0037] In the electric discharge section 40 configured as described above, when a periodically changing voltage is applied between the first electrode 42 and the second electrode 44, creeping discharge occurs in the intermediate flow channel 36. Plasma produced as a result of the creeping discharge is discharged to the outside space through the discharge opening 34 by the gas supplied from the gas supply section 7 into the intermediate flow channel 36. Notably, in the example of FIG. 6, the intermediate flow channel 36 has a constant width in the region AR1 in the first direction, and, in the region AR2, the width of the intermediate flow channel 36 decreases toward the forward end side, whereby the flow speed of the gas can be increased in the vicinity of the discharge opening 34. Accordingly, the plasma produced in the intermediate flow channel 36 easily reaches a further point.

2. Details of power supply section

[0038] The power supply section 9 applies a periodically changing voltage between the first electrode 42 and the second electrode 44 at a high frequency. In the first embodiment and any of embodiments, other than the first embodiment, which will be described later, the frequency of the voltage applied between the first electrode 42 and the second electrode 44 by the power supply section 9 desirably falls within the range of 20 kHz to 300 kHz. Also, in the first embodiment and any of embodiments, other than the first embodiment, which will be described later, the voltage applied between the first electrode 42 and the second electrode 44 by the power supply section 9 is desirably adjusted such that the maximum value of the potential difference between the first electrode 42 and the second electrode 44 falls within the range of 0.5 kV to 10 kV. Any of various known AC circuits and DC circuits can be employed as the power supply section 9 so long as the employed circuit can generate a high voltage having a high frequency as described above. Notably, in the present specification, the application voltage applied between the first electrode 42 and the second electrode 44 is represented by the magnitude of the relative potential of the first electrode 42 in relation to the potential of the second electrode 44 serving as a reference. In the case where the potential of the first electrode 42 is represented by V1 and the potential of the second electrode 44 is represented by V2, the above-described applied voltage is V1 - V2.

[0039] In the first embodiment and any of embodiments, other than the first embodiment, which will be described later, the waveform of the voltage applied between the first electrode 42 and the second electrode 44 by the power supply section 9 is a waveform which changes periodically, for example, in such a manner that a convex waveform and a concave waveform alternately and repeatedly appear. Although the waveform of the applied voltage may be a curved waveform such as sinusoidal waveform, a rectangular waveform, a triangular waveform, etc.

[0040] FIG. 7 shows, as an example, the voltage waveform employed by the power supply section 9 in the solution processing apparatus 1 of the first embodiment. In the graph of FIG. 7, the vertical axis shows the application voltage applied between the first electrode 42 and the second electrode 44, and the horizontal axis shows time (elapsed time). FIG. 7 shows change with time in the above-described application voltage (V1 - V2) applied by the power supply section 9. In FIG. 7, the convex waveform is a waveform which is convex toward one side in the vertical direction (specially, the side of high voltage). The concave waveform is a waveform which is concave from the one side in the vertical direction and is convex toward the other side in the vertical direction (specially, the side of low voltage). In the waveform of the application voltage shown in FIG. 7, the above-described convex waveform and the above-described concave waveform appear in a single period T from time t1 to time t2, and such a voltage waveform in the single period T is periodically repeated over a plurality of periods. The power supply section 9 applies an AC voltage between the first electrode 42 and the second electrode 44 over a plurality of periods, the AC voltage having a waveform as shown in FIG. 7 in each single period T. Notably, the specific value of the application voltage shown in FIG. 7 and the specific value of time (elapsed time) shown in FIG. 7 are preferred examples, and the value of the application voltage and the value of time (elapsed time) are not limited to those shown in FIG. 7.

[0041] In the waveform of the above-described application voltage shown in FIG. 7, the convex waveform in each period is a voltage waveform containing the maximum voltage value (peak voltage value) in each period, and the voltage waveform is a rising waveform, representing a voltage increase, up to a time when the voltage reaches the maximum voltage value in each period, and is a falling waveform, representing a voltage decrease, after the time when the voltage has reached the maximum voltage value. The rising waveform of the convex waveform may contain a waveform representing a temporary voltage fall, and the falling waveform of the convex waveform may contain a waveform representing a temporary voltage rise. The positive peak voltage value in each period is equal to the difference between 0 V and the maximum voltage value in each period (specifically, a value obtained by subtracting 0 V from the maximum voltage value). In FIG. 7, a voltage value Va1 is shown as an example of the positive peak voltage value in the period T. The voltage value Va1 is a positive value. The concave waveform in each period is a voltage waveform containing the minimum voltage value in each period, and the voltage waveform is a falling waveform, representing a voltage decrease, up to a time when the voltage reaches the minimum voltage value in each period, and is a rising waveform, representing a voltage increase, after the time when the voltage has reached the minimum voltage value. The falling waveform of the concave waveform may contain a waveform representing a temporary voltage rise, and the rising waveform of the concave waveform may contain a waveform representing a temporary voltage fall. The negative peak voltage value in each period is equal to the difference between 0 V and the minimum voltage value in each period (specifically, a value obtained by subtracting 0 V from the minimum voltage value). In FIG. 7, a voltage value Vb1 is shown as an example of the negative peak voltage value in the period T. The voltage value Vb1 is a negative value.

[0042] As shown in FIG. 7, the waveform of the application voltage applied between the first electrode 42 and the second electrode 44 by the power supply section 9 is a positively biased waveform representing that the average of the positive peak voltage value and the negative peak voltage value in each period is positive. In the example shown in FIG. 7, the value of (Va1 + Vb1)/2 is positive. For example, in the case where an application voltage having a waveform as shown in FIG. 7 is applied between the first electrode 42 and the second electrode 44 for a predetermined period of time (for example, a predetermined number of periods), when the average of positive peak voltage values in the predetermined period of time is represented by Av1 and the average of negative peak voltage values in the predetermined period of time is represented by Av2, the total sum of the average value Av 1 and the average value Av2 is also positive.

[0043] In the solution processing apparatus 1, the power supply section 9 applies the application voltage having the positively biased waveform as shown in FIG. 7 to the first electrode 42 and the second electrode 44 so as to cause the electric discharge section 40 to perform a discharge operation (plasma irradiation operation) such that current having a waveform as shown in FIG. 8 flows through the solution 90.

[0044] The graph of FIG. 8 shows the change with time in leakage current which flows from the solution 90 to the ground side through the container 80 when plasma generated by applying voltage (AC voltage) having a waveform as shown in FIG. 7 to the electric discharge section 40 is applied to the solution 90 (specifically, solution containing blood proteins) within the container 80. In FIG. 8, the vertical axis shows the value of the above-described leakage current, and the horizontal axis shows time (elapsed time). As to the direction of leakage current flowing from the solution 90 to the ground portion 98 side through the container 80, the direction from the container 80 toward the ground portion 98 is defined as a positive direction. Time t1 in FIG. 8 corresponds to time t1 in FIG. 7, and time t2 in FIG. 8 corresponds to time t2 in FIG. 7. In the case where the application voltage is applied in the period T from time t1 to time t2 as shown in FIG. 7, leakage current flowing through the solution 80 in that period T has a waveform shown in FIG. 8; specifically, a waveform in the period from time t1 to time t2 in FIG. 8. Notably, the specific value of leakage current and the specific value of time (elapsed time) shown in FIG. 8 are preferred examples, and the value of leakage current and the value of time (elapsed time) are not limited to those shown in FIG. 8.

[0045] As shown in FIG. 8, the current flowing through the solution 90 (specifically, leakage current flowing from the solution 90 to the ground portion 98) in the above-described predetermined period of time (for example, a period of time corresponding to a predetermined number of periods T) has a waveform in which a waveform representing positive current values and a waveform representing negative current values are alternately repeated. Furthermore, the waveform of the current flowing through the solution 90 in the above-described predetermined period of time is a waveform in which the average of current values substantially becomes 0 in each period. Specifically, in any period in the above-described predetermined period of time, the absolute value of the average of current values in a period under consideration is 1/10 or less of the effective value of the current in that period under consideration. For example, in the period of time (period T) shown in FIG. 8, the absolute value of the average of current values in that period of time (period T) is 1/10 or less of the effective value of the current in that period of time (period T). Furthermore, the waveform of the current flowing through the solution 90 in the above-described period of time is a waveform in which the absolute value of the positive peak current value is greater than the absolute value of the negative peak current value in each period. For example, in the period of time (period T) shown in FIG. 8, a current value Ia1 is shown as an example of the positive peak current value, and a voltage value Ib1 is shown as an example of the negative peak current value. Ia1 is a positive value, Ib1 is a negative value, and the absolute value of Ia1 is greater than the absolute value of Ib1. The power supply section 9 causes the electric discharge section 40 to perform the discharge operation in such a manner that the current flowing through the solution 90 in the above-described predetermined period of time has such a waveform.

3. Operation of solution processing apparatus

[0046] The above-described solution processing apparatus 1 shown in FIG. 1 can be used in a solution processing method which will be described below. This solution processing method is a method for processing the blood protein containing solution 90 by using the solution processing apparatus 1 and includes mainly a preparation step and an irradiation step.

[0047] The preparation step is a step of preparing the blood protein containing solution 90. Specifically, the preparation step is a step of preparing the above-described plasma irradiation apparatus 2, the above-described container 80, and the above-described blood protein containing solution 90, and of placing the blood protein containing solution 90 into the container 80 for preparation. For example, a worker can perform the work of preparing the plasma irradiation apparatus 2, the container 80, and the solution 90. The worker can also perform the preparation work of placing the solution 90 into the container 80. Notably, a portion or the entirety of the work of the preparation step may be performed mechanically by an apparatus. Also, the solution 90 may be prepared by any method.

[0048] The irradiation step is a step of applying plasma to the solution 90, which is prepared in the preparation step, by using the solution processing apparatus 1. In the irradiation step, the plasma irradiation section 20 is disposed in such a manner that the discharge opening 34 faces toward the solution 90 within the container 80, and, in this state, the plasma irradiation section 20 applies characteristic plasma to the solution 90.

[0049] In the irradiation step, an inert gas (for example, rare gas such as helium gas) is supplied from the gas supply section 7, so that the inert gas flows through the space within the gas flow channel 30. In the irradiation step, in a state in which the inert gas is flowing through the gas flow channel 30 as described above, the power supply section 9 applies a periodic voltage having the above-described voltage waveform between the first electrode 42 and the second electrode 44 such that leakage current has the above-described current waveform. The above-described voltage waveform is the above-described "positively biased waveform" as illustrated in FIG. 7. The above-described current waveform is a waveform as illustrated in FIG. 8; specifically, "in the waveform representing values of current flowing through the solution 90, a waveform representing positive current values and a waveform representing negative current values are alternately repeated, the average of current values becomes substantially 0 in each period, and the absolute value of the positive peak current value is greater than the absolute value of the negative peak current value in each period." When the periodic voltage having the above-described voltage waveform is applied between the first electrode 42 and the second electrode 44, as described above, in a state in which the inert gas is flowing through the gas flow channel 30, creeping discharge occurs in the space within the gas flow channel 30. Plasma generated as a result of this creeping discharge is discharged from the discharge opening 34 toward the solution 90. In this creeping discharge, for example, in each period of the periodically applied AC voltage, the generation amount of positively charged plasma is made equal to the generation amount of negatively charged plasma.

[0050] As described above, in the irradiation step, the plasma irradiation section 20 generates plasma by applying the voltage having a characteristic voltage waveform between the electrodes, and applies to the solution 90 plasma which has a characteristic property according to the voltage waveform. The plasma applied to the solution 90 is charged plasma. In the case where plasma is applied over the above-described predetermined period of time (for example, a plurality of periods), the amount of positively charged plasma generated in each period is made equal to the amount of negatively charged plasma generated in each period, and the amount of positively charged plasma generated in the entirety of the predetermined period of time is made equal to the amount of negatively charged plasma generated in the entirety of the predetermined period of time. When the charged plasma is applied to the solution 90, as a result of flow of charged particles, current (the above-described leakage current) flows between the solution 90 and the ground portion 98. Notably, the flow direction of the leakage current changes between the case where plasma in which positive charge is predominant is applied to the solution 90 and the case where plasma in which negative charge is predominant is applied to the solution 90. As a result of flow of such current, aggregation of blood proteins within the solution 90 occurs.

[0051] The power supply section 9 causes the electric discharge section 40 to perform the discharge operation in such a manner that, in each period, the absolute value of the positive peak current value becomes greater than the absolute value of the negative peak current value. Namely, in the case where current flows through the solution 90 in the positive direction due to positively charged particles, since the current has a relatively large peak current value and changes sharply, negatively charged blood proteins can be efficiently aggregated in the solution 90. This effect becomes more remarkable, for example, in the case of a solution in which the amount of negatively charged blood proteins is greater than the amount of positively charged blood proteins.

[0052] However, in the case where the charge provided to the solution 90 by plasma irradiation is excessively biased to the positive side or the negative side, the current becomes more likely to flow to a deep portion of the solution 90. This is undesirable in the case where electrification of the deep portion must be suppressed. In view of this, the solution processing apparatus 1 supplies current to the solution 90 in such a manner that the average of current values becomes substantially 0 in each period. As a result of such an operation, excessive flow of current to the deep portion of the solution 90 can be suppressed. Such an operation enables, for example, processing of solidifying a surface portion of the solution 90, by selectively aggregating blood proteins, while preventing or suppressing the aggregation in the deep portion of the solution 90 (a region deeper than a region where blood proteins are to be aggregated).

[0053] The solution processing apparatus 1 has a configuration in which one of the first electrode 42 and the second electrode 44 (the first electrode 42 in the example of FIG. 5) faces the space within the gas flow channel 30 via another member (the second dielectric layer 52) and creeping discharge is generated within the gas flow channel 30 through application of voltage between the first electrode 42 and the second electrode 44. Since the electric discharge section 40 is configured to generate creeping discharge as described above, plasma can be applied more efficiently by using a lower application voltage.

<Second embodiment>

[0054] The following description relates to a solution processing apparatus 201 of a second embodiment illustrated in FIG. 9. The solution processing apparatus 201 of FIG. 9 is the same as the solution processing apparatus 1 of the first embodiment except the points that the solution processing apparatus 201 has a resistance element 202, and the material of the container 80 differs from the material of the container 80 in the first embodiment. Therefore, the following description emphasizes mainly a matter relating to the resistance element 202.

[0055] The plasma irradiation apparatus 2 used in the solution processing apparatus 201 has a configuration identical with that of the plasma irradiation apparatus 2 in the solution processing apparatus 1 of the first embodiment and performs the same operation as the plasma irradiation apparatus 2 in the first embodiment.

[0056] The container 80 used in the solution processing apparatus 201 has a configuration identical with that of the container 80 in the solution processing apparatus 1 of the first embodiment. However, the container 80 of the second embodiment is formed of electrically conductive glass. Accordingly, the solution processing apparatus 201 can secure some resistance at the container 80 and can control the current flowing to the ground portion 98 side through the container 80. The solution 90 contained in the container 80 may be any of examples of the solution 90 described in the first embodiment.

[0057] In the solution processing apparatus 201, the container 80 is connected to the ground portion 98 through the resistance element 202. The resistance element 202 has a function of offsetting the potential of the container 80 from the potential of the ground portion 98. Specifically, the resistance element 202 includes a variable resistor 202A. The variable resistor 202A intervenes between the outer surface portion 80B of the container 80 having electrical conductivity and the ground portion 98. When the potential of the outer surface portion 80B is higher than the potential of the ground portion 98, current flows from the outer surface portion 80B through the variable resistor 202A. In this example, when current flows from the container 80 to the ground portion 98 through the variable resistor 202A, the potential of the container 80 becomes higher than that of the ground portion 98 because of a voltage drop produced at the variable resistor 202A.

[0058] The solution processing apparatus 201 can achieve effects similar to those achieved by the solution processing apparatus 1 of the first embodiment. Furthermore, since the resistance element 202 is present, the solution processing apparatus 201 can control the current flowing to the ground portion 98 side.

<Other embodiments>

[0059] The present disclosure is not limited to the embodiments described by the above description with reference to the drawings. The features of the above-described embodiments and embodiments which will be described below can be combined in any manner so long as no contradiction occurs. Also, any of the features of the above-described embodiments and the embodiments which will be described below can be omitted so long as it is not clearly described as essential. Furthermore, the features of the above-described embodiments may be changed as follows.

[0060] In the solution processing apparatuses of the above-described embodiments, as shown in FIG. 5, the first electrode 42 faces the space within the gas flow channel 30 with the second dielectric layer 52, which is another member, intervening therebetween. However, the first electrode 42 may face the space within the gas flow channel 30 in a state in which another member does not intervene therebetween. Namely, the solution processing apparatus may be configured such that the first electrode 42 is exposed to the space within the gas flow channel 30, and the first electrode 42 forms a portion of the inner wall of the gas flow channel 30.

[0061] In the above-described examples, the first electrode faces the space within the gas flow channel directly or with another member intervening therebetween. However, the second electrode may face the space within the gas flow channel directly or with another member intervening therebetween. For example, the second electrode may be covered with a dielectric layer, which is "another member," so that the second electrode faces the space within the gas flow channel with the dielectric layer intervening therebetween. Alternatively, the solution processing apparatus may be configured such that the second electrode is exposed to the space within the gas flow channel, and the second electrode forms a portion of the inner wall of the gas flow channel. In either case, what is required is that the first electrode is disposed at a position more remote from the gas flow channel as compared with the second electrode.

[0062] In the above-described embodiments, the container 80 is formed of resin or electrically conductive glass. However, the container 80 may be formed of any of other materials having electrical conductivity (for example, metallic materials). Alternatively, the container 80 may be formed of a material which does not have electrical conductivity.

[0063] Although the above-described embodiments employ the configuration for applying plasma to the solution 90 contained in the container 80, the present disclosure is not limited to this example. For example, a solution processing method may be performed in such a manner that the above-described plasma irradiation apparatus 2 applies plasma to a "blood protein containing solution, which is not contained in a container," so that an aggregation action occurs in this solution. In this method, the plasma irradiation apparatus 2 can be functioned as the solution processing apparatus. In the preparation step, the above-described plasma irradiation apparatus 2 is prepared, and the blood protein containing solution is disposed at a position at which the blood protein containing solution can be irradiated with plasma from the plasma irradiation apparatus 2. Subsequently, in the irradiation step, plasma is applied, by the plasma irradiation apparatus 2, to the solution disposed at the position at which the blood protein containing solution can be irradiated with plasma from the plasma irradiation apparatus 2. In this example, the "blood protein containing solution, which is not contained in a container" may be a solution which is present on the surface or in the interior of, for example, an animal or a human body, or any of other solutions which are not contained in containers.

[0064] In the solution processing apparatus 201 of the second embodiment, the variable resistor 202A is provided as the resistance element 202. However, in place of the variable resistor 202A or in addition to the variable resistor 202A, an electrical component such as an inductor, a capacitor, etc. may be provided as the resistance element. The resistance element 202 may have any configuration so long as current flows from the container 80 to the ground portion 98 through the resistance element 202 and the potential of the container 80 becomes higher than the potential of the ground portion 98 due to presence of the resistance element 202. For example, the resistance element 202 may be a voltage generation circuit which maintains the potential of the container 80 at a predetermined potential which is offset from the potential of the ground portion 98 by a certain amount.

[0065] In the above-described embodiments, the periodic voltage waveform shown in FIG. 7 is employed as an example. However, the periodic voltage waveform is not limited to that example. The waveform of the periodic voltage applied to the two electrodes by the power supply section 9 may be a curved waveform such as a sinusoidal waveform, a rectangular waveform, a triangular waveform, or the like. In any case, the waveform may be freely determined so long as the waveform enables the electric discharge section to perform an operation of applying plasma to blood proteins over a predetermined period of time such that particles charged to one of positive and negative polarities are applied to the blood proteins in a greater amount as compared with particles charged to the other polarity.

[0066] Notably, the embodiments disclosed this time should be considered to be illustrative and not to be restrictive in all aspects. The scope of the present invention is not limited to the embodiments disclosed this time, and it is intended that the present invention encompasses all modifications within the range shown by the claims and the range of equivalents of the claims.

REFERENCE SIGNS LIST

[0067]

1, 201: solution processing apparatus
5: control section
9: power supply section
20A: main body portion
30: gas flow channel
34: discharge opening
40: electric discharge section
42: first electrode
44: second electrode
50: dielectric layer
80: container
90: solution
98: ground portion
P: plasma

Claims

1. A solution processing apparatus which applies plasma to a solution containing proteins derived from blood, comprising:

   a main body portion having a gas flow channel which has a discharge opening for gas and through which the gas flows toward the discharge opening;
   an electric discharge section which includes a dielectric layer and a first electrode and a second electrode disposed to face each other with the dielectric layer intervening therebetween and which generates plasma discharge within the gas flow channel; and
   a power supply section for applying voltage between the first electrode and the second electrode,
   wherein the power supply section periodically applies AC voltage between the first electrode and the second electrode, thereby causing the electric discharge section to perform a discharge operation in such a manner that, in a

waveform representing values of current flowing through the solution, a waveform representing positive current values and a waveform representing negative current values are alternately repeated, the average of the current values becomes substantially 0 in each period, and the absolute value of a positive peak current value becomes larger than the absolute value of a negative peak current value in each period.

2. A solution processing apparatus according to claim 1, wherein, in the electric discharge section, one of the first electrode and the second electrode faces a space within the gas flow channel directly or with another member intervening therebetween, and creeping discharge is generated within the gas flow channel as a result of application of the voltage between the first electrode and the second electrode.

3. A solution processing apparatus according to claim 1 or 2, wherein the gas is a rare gas.

4. A solution processing apparatus according to claim 3, wherein the gas is helium gas.

5. A solution processing apparatus according to any one of claims 1 to 4, further comprising a container which contains the solution.

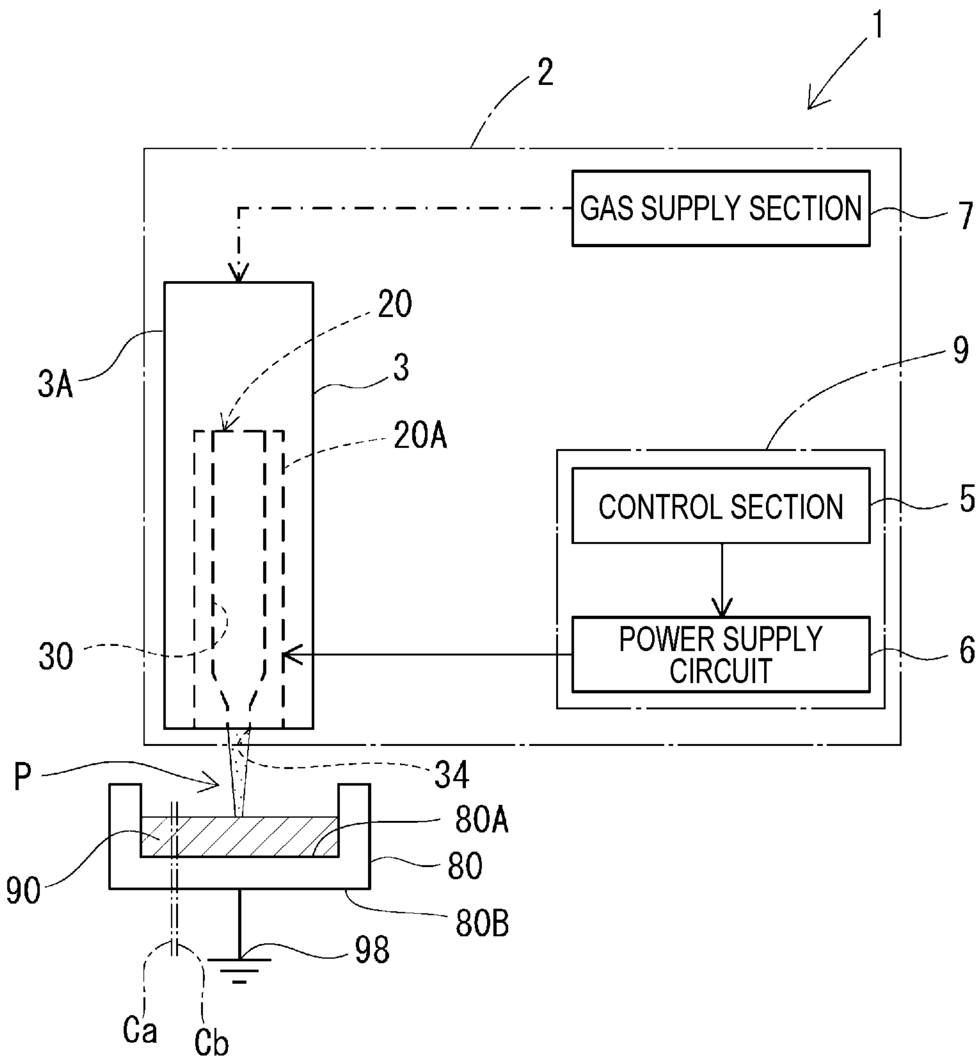
6. A solution processing apparatus according to claim 5, wherein the container has electrical conductivity and is electrically connected to a ground portion.

7. A solution processing apparatus according to claim 5 or 6, wherein the container is formed of electrically conductive glass.

8. A solution processing method for processing a solution containing proteins derived from blood by using a solution processing apparatus comprising a main body portion having a gas flow channel which has a discharge opening for gas and through which the gas flows toward the discharge opening, an electric discharge section which includes a dielectric layer and a first electrode and a second electrode disposed to face each other with the dielectric layer intervening therebetween and which generates plasma discharge within the gas flow channel; and a power supply section for applying voltage between the first electrode and the second electrode,

wherein the solution processing method comprises an irradiation step of applying plasma to the solution by the solution processing apparatus, and
wherein, in the irradiation step, the power supply section periodically applies AC voltage between the first electrode and the second electrode, thereby causing the electric discharge section to perform a discharge operation in such a manner that, in a waveform representing values of current flowing through the solution, a waveform representing positive current values and a waveform representing negative current values are alternately repeated, the average of the current values becomes substantially 0 in each period, and the absolute value of a positive peak current value becomes larger than the absolute value of a negative peak current value in each period.

FIG. 1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7
20
3A
3
9
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6
P
34
80A
90
80
80B
98
Ca
Cb

FIG. 2

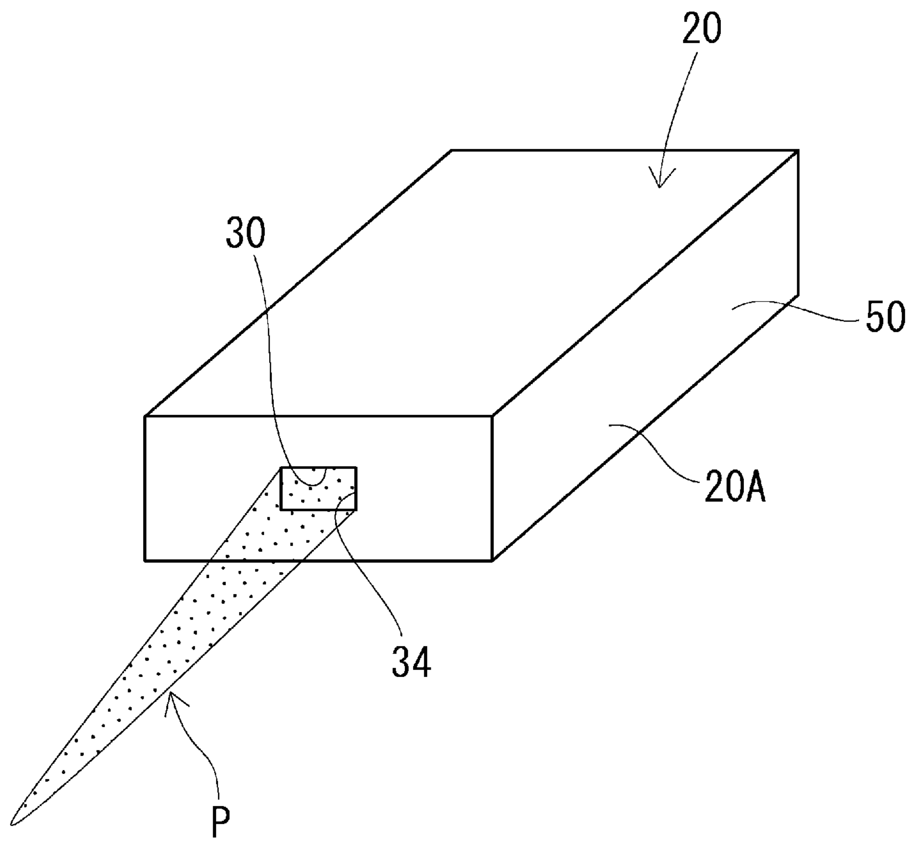


FIG. 3

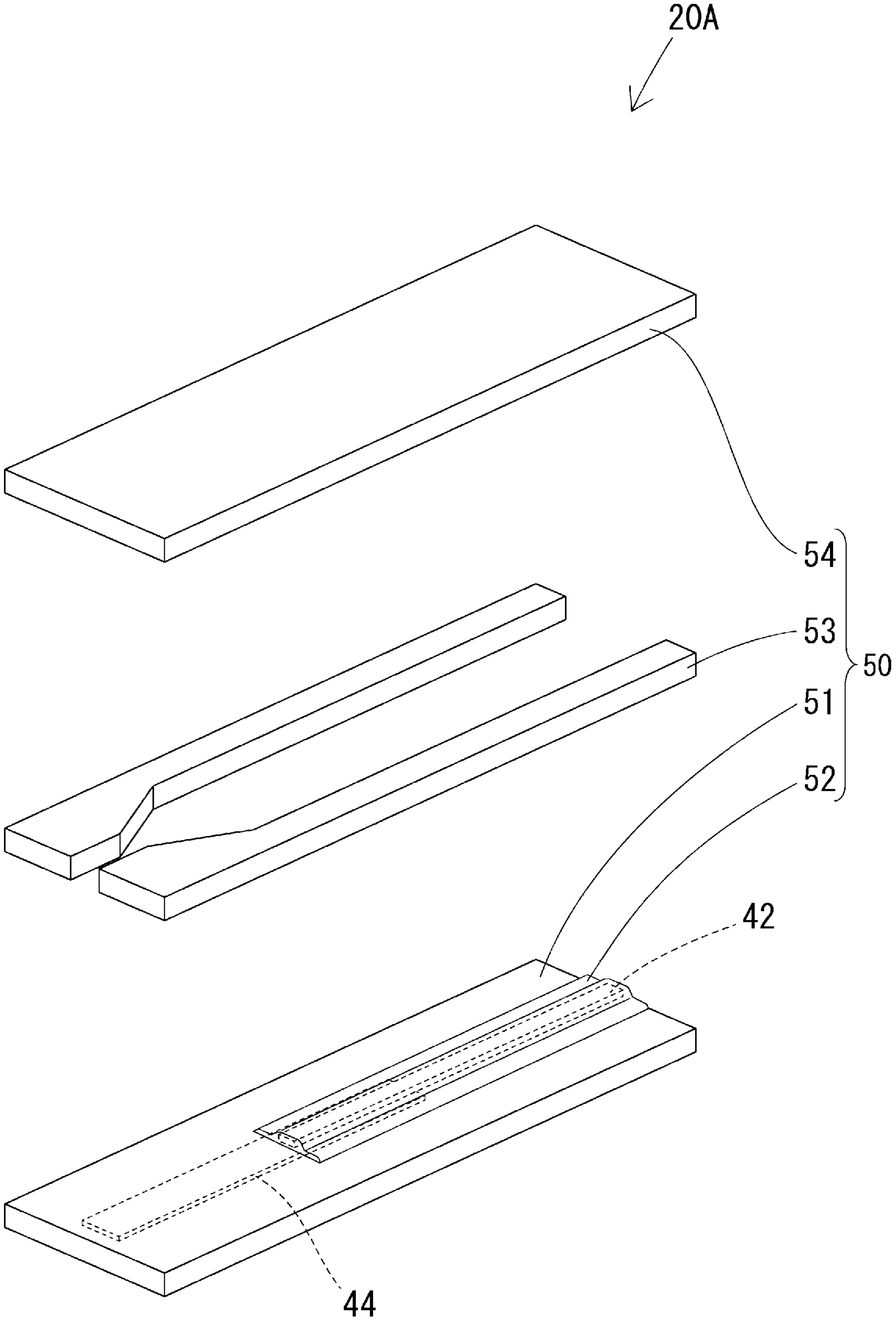
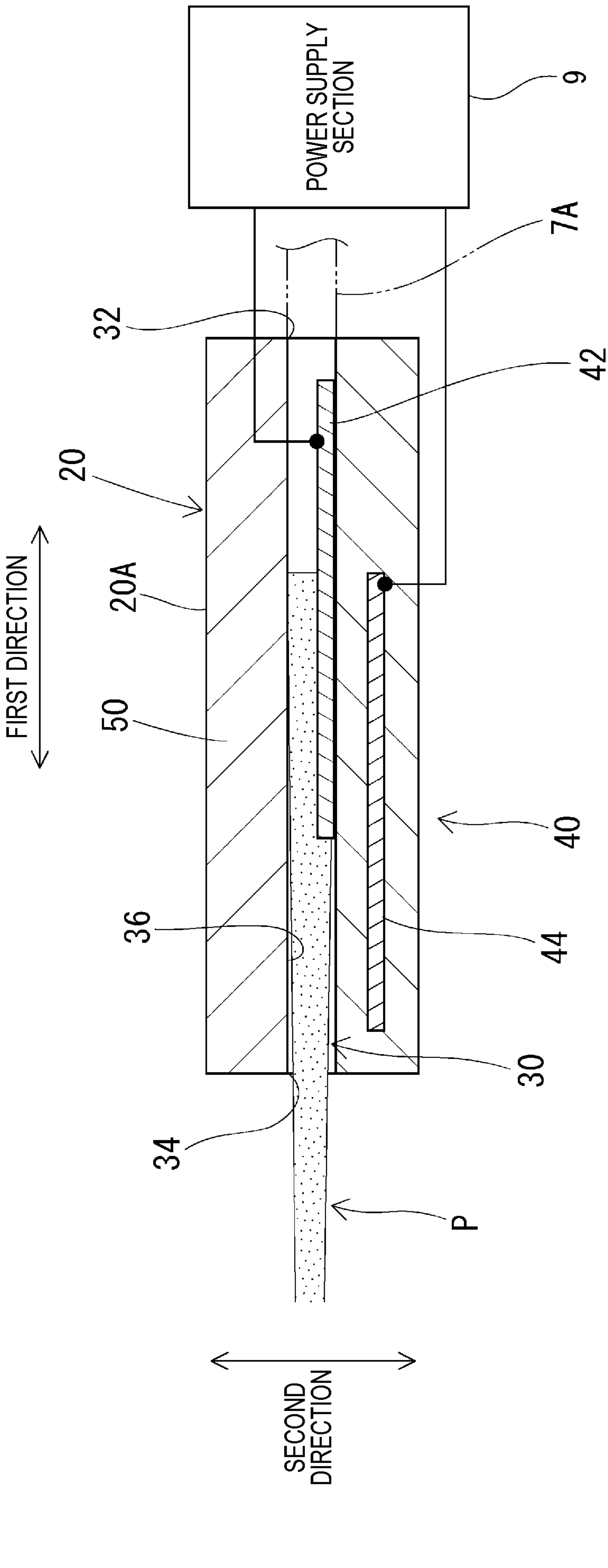


FIG. 4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20A
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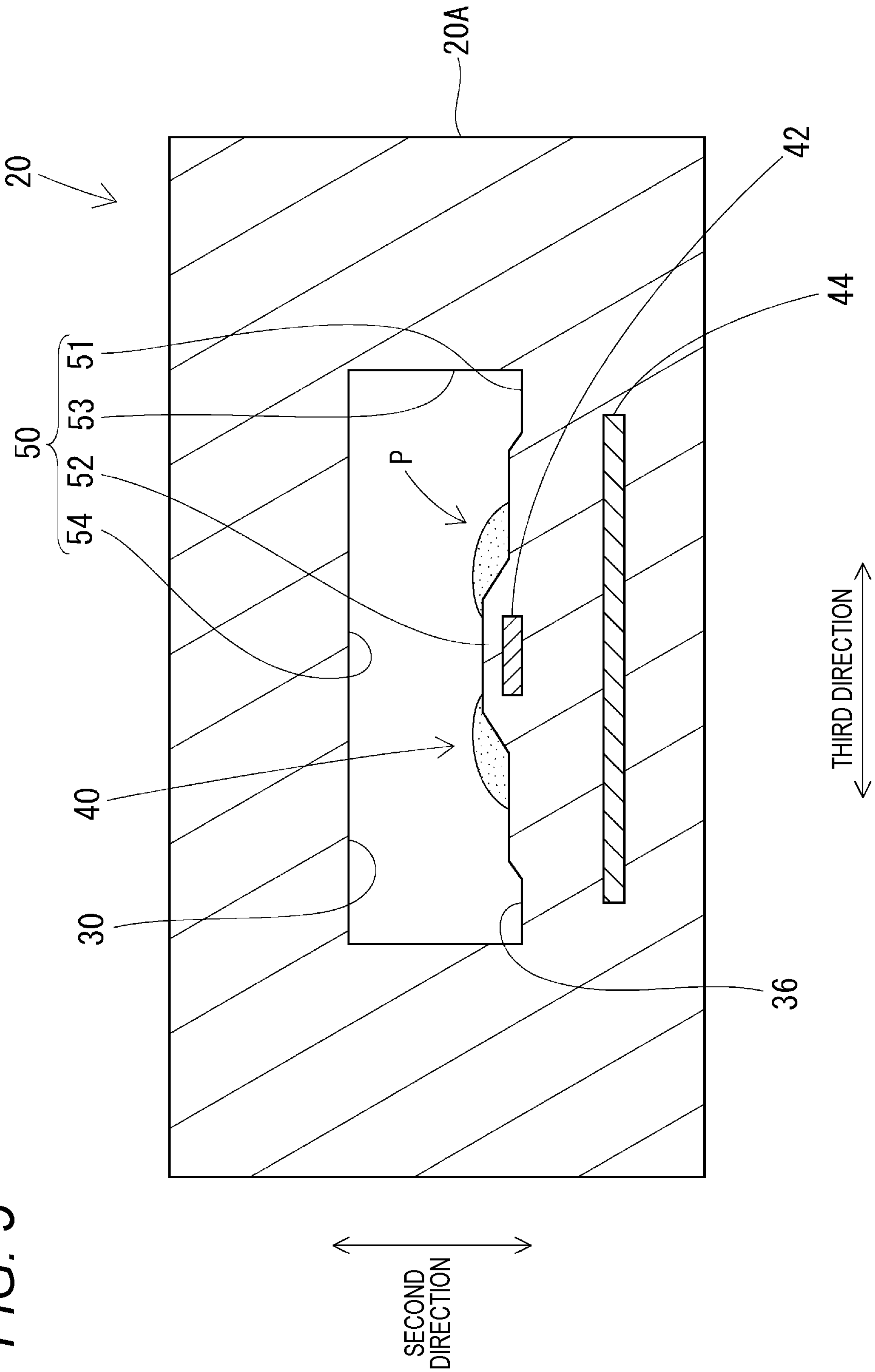
34
P
SECOND DIRECTION

FIG. 5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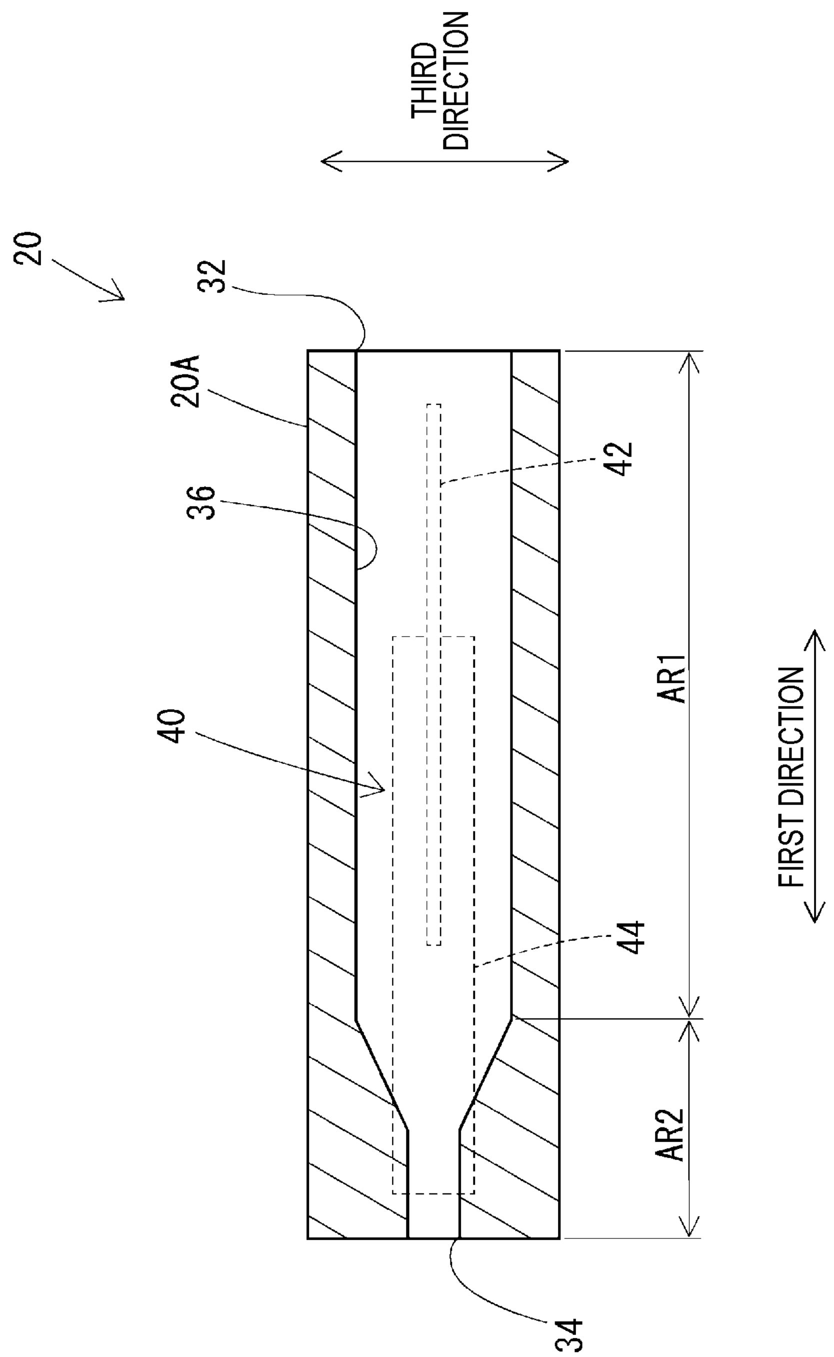
36
THIRD DIRECTION
SECOND DIRECTION

FIG. 6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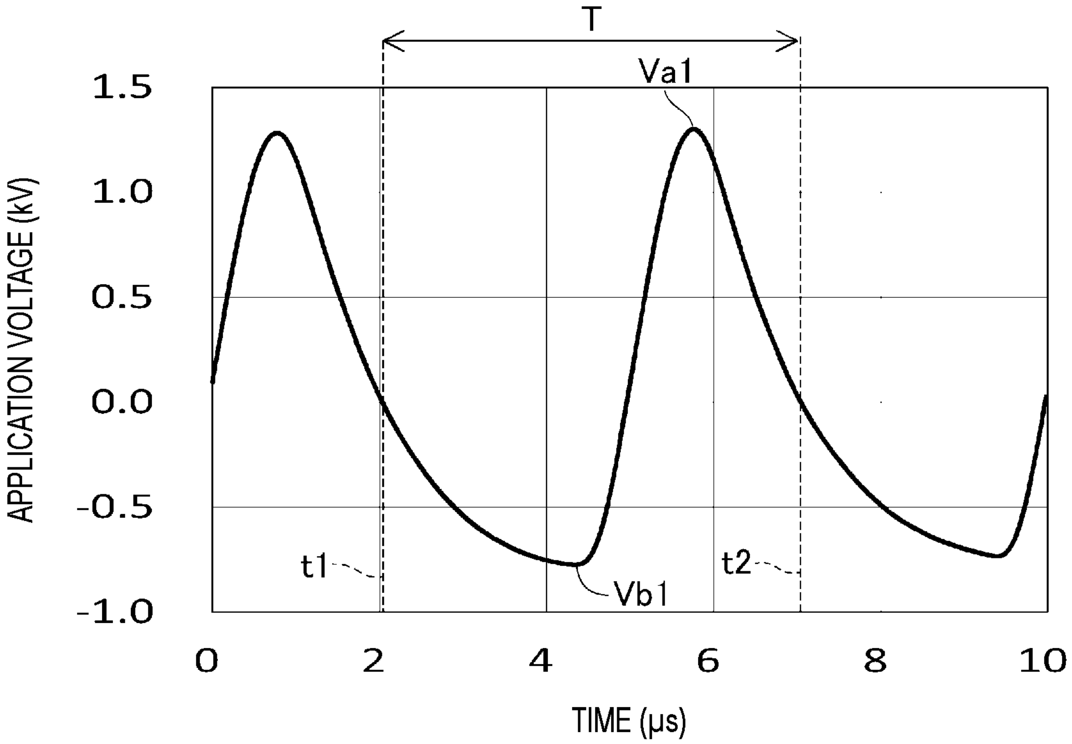
32
20A
36
40
42
44
AR1
AR2
FIRST DIRECTION
34

FIG. 7


T
Va1
Vb1
t1
t2
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1.0
0.5
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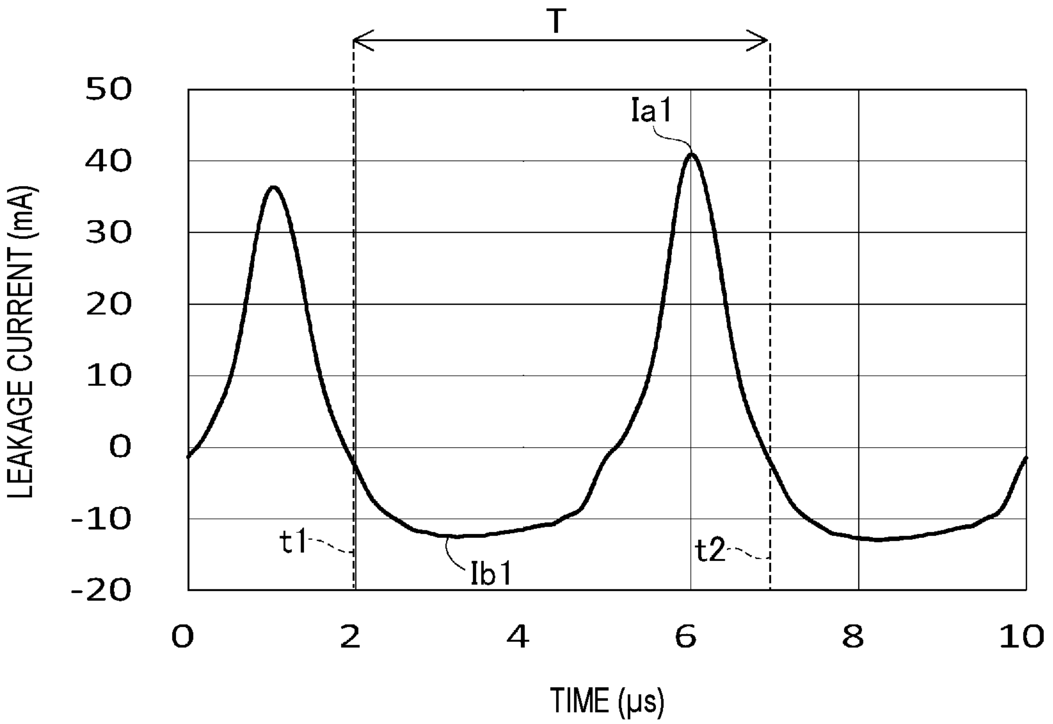
2
4
6
8
10
TIME (μs)

FIG. 8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t2
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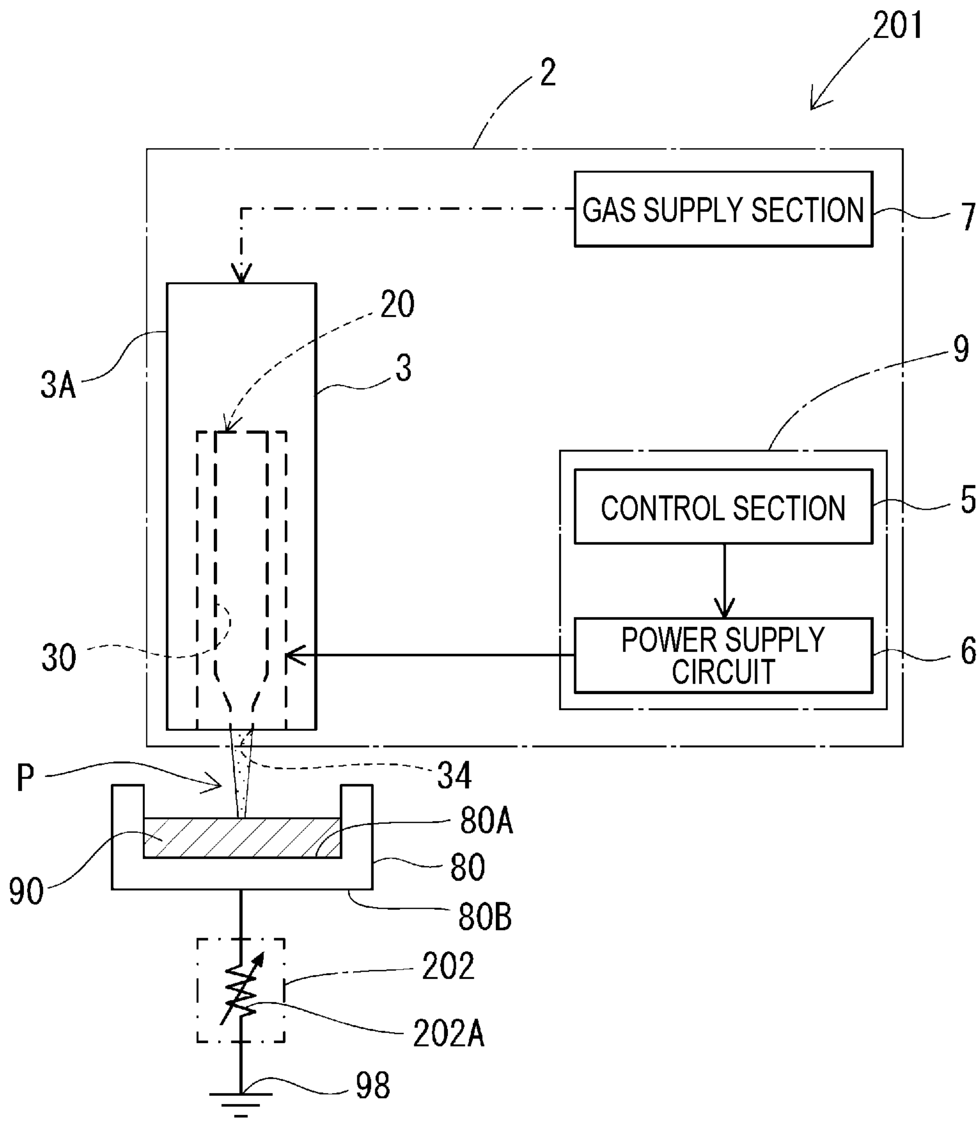
8
10
TIME (μs)

FIG. 9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GAS SUPPLY SECTION
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CONTROL SECTION
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P
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80A
90
80
80B
202
202A
98

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2022/047815

A. CLASSIFICATION OF SUBJECT MATTER

H05H 1/26(2006.01)i; ***G01N 33/48***(2006.01)i
FI: H05H1/26; G01N33/48 B

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)

H05H1/00-1/54; G01N33/48

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

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2023
Registered utility model specifications of Japan 1996-2023
Published registered utility model applications of Japan 1994-2023

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2020-198252 A (NGK SPARK PLUG CO) 10 December 2020 (2020-12-10) entire text, all drawings	1-8
A	JP 2020-198238 A (NGK SPARK PLUG CO) 10 December 2020 (2020-12-10) entire text, all drawings	1-8
A	JP 2019-150566 A (GYRUS ACMI INC) 12 September 2019 (2019-09-12) abstract, fig. 1	1-8
A	JP 2021-26811 A (NIHON DENSAN KK) 22 February 2021 (2021-02-22) paragraphs [0011]-[0036], fig. 1-2	1-8
A	JP 2020-145038 A (NIHON DENSAN KK) 10 September 2020 (2020-09-10) paragraphs [0014]-[0037], fig. 1-3	1-8

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
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"E" earlier application or patent but published on or after the international filing date
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"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
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
02 February 2023	**14 February 2023**

Name and mailing address of the ISA/JP	Authorized officer
Japan Patent Office (ISA/JP) **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2022/047815

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JP 2020-198238 A	10 December 2020	US 2022/0053628 A1 entire text, all drawings WO 2020/246435 A1 EP 3982698 A1 CN 113287372 A	
JP 2019-150566 A	12 September 2019	US 2019/0262058 A1 abstract, fig. 1 EP 3533378 A1 CN 110200695 A	
JP 2021-26811 A	22 February 2021	(Family: none)	
JP 2020-145038 A	10 September 2020	CN 111669885 A paragraphs [0028]-[0052], fig. 1-3	

Form PCT/ISA/210 (patent family annex) (January 2015)

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