US 20120153055A1

(19) United States
(12) Patent Application Publication
Imai et al.
(10) Pub. No.: US 2012/0153055 A1
(43) Pub. Date: Jun. 21, 2012

(54) ELECTROSTATIC ATOMIZATION DEVICE

(75) Inventors: **Bungo Imai**, Osaka (JP); **Hiroyasu Kitamura**, Osaka (JP); **Mikihiro Yamashita**, Shiga-ken (JP)

(73) Assignee: **Panasonic Corporation**, Osaka (JP)

(21) Appl. No.: **13/393,360**

(22) PCT Filed: **Sep. 13, 2010**

(86) PCT No.: **PCT/JP2010/066116**

§ 371 (c)(1), (2), (4) Date: **Feb. 29, 2012**

(30) **Foreign Application Priority Data**

Sep. 25, 2009 (JP) 2009-220458

Publication Classification

(51) **Int. Cl.**
F23D 11/32 (2006.01)

(52) **U.S. Cl.** **239/690**

(57) **ABSTRACT**

An electrostatic atomization device provided with a transformer including primary and secondary coils. A switching element is connected in series to the primary coil. A switching element drive circuit provides the switching element with a pulse signal to perform a switching operation and generate high voltage from the secondary coil. A discharge unit including a discharge electrode performs electrostatic atomization on liquid supplied to the discharge electrode to generate charged fine liquid droplets when high voltage generated by the secondary coil is applied to the discharge electrode. The switching element drive circuit generates a pulse signal having an oscillation frequency set so that the transformer has drooping characteristics that prevent air discharge from occurring between the discharge electrode and ground even when load on the discharge unit varies and prevents the generation of ozone having a predetermined concentration or greater when the liquid undergoes electrostatic atomization.

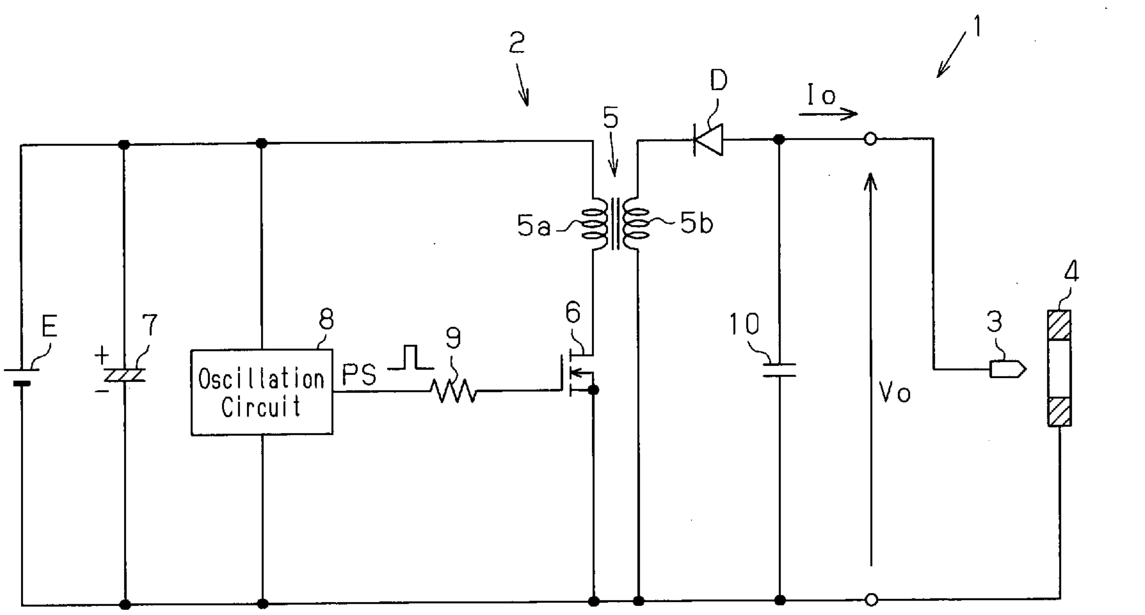


Fig.1

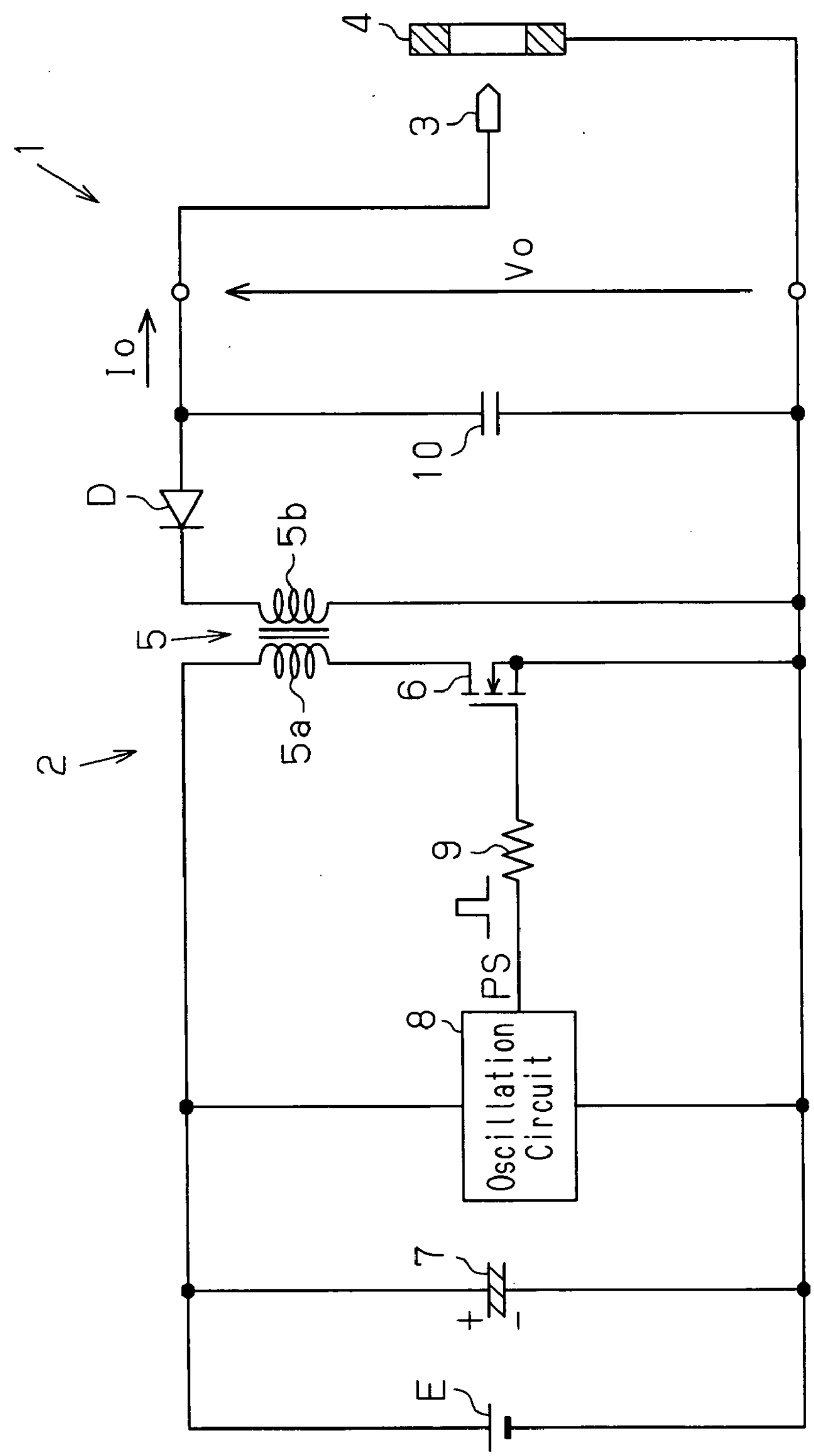


Fig.2

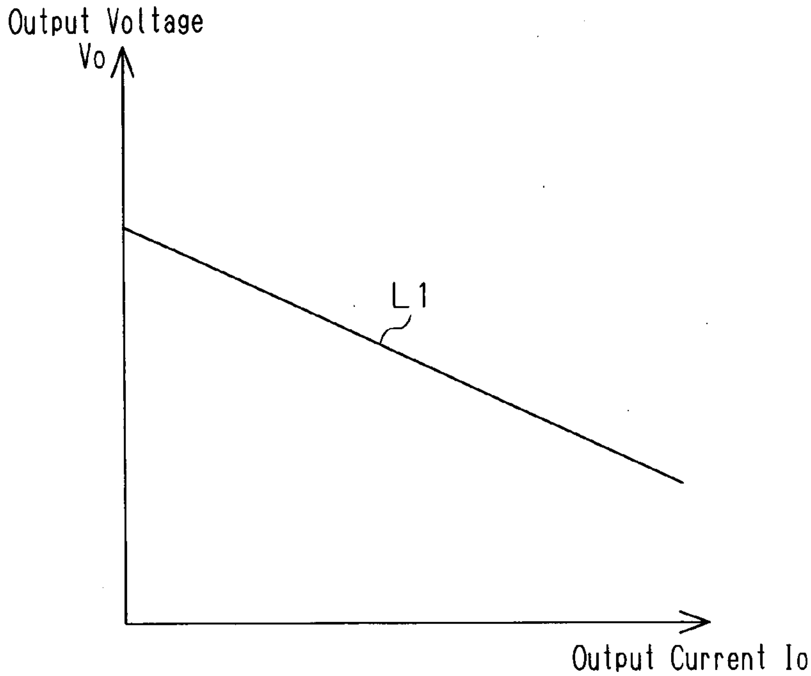

Output Voltage
Vo
L1
Output Current Io

Fig.3

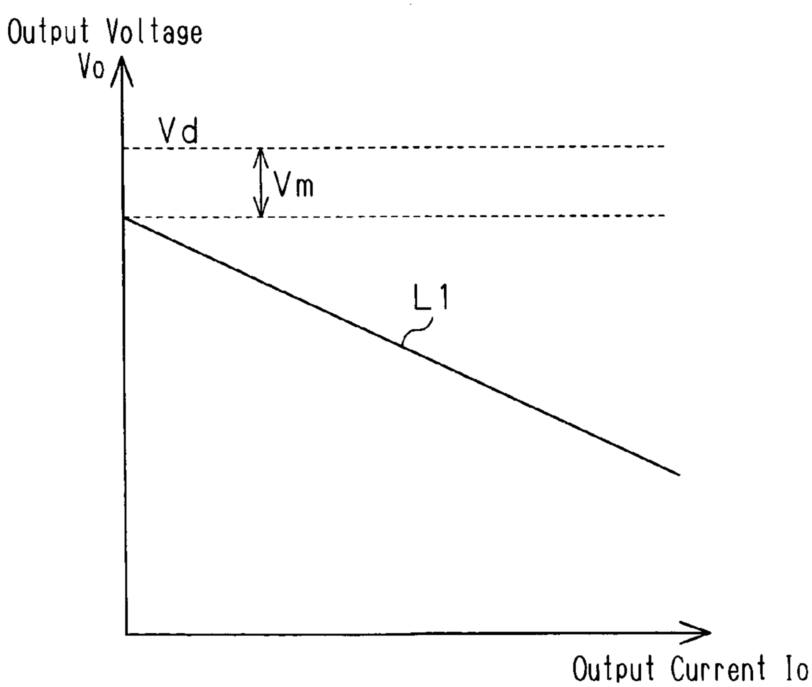

Output Voltage
Vo
Vd
Vm
L1
Output Current Io

Fig.4

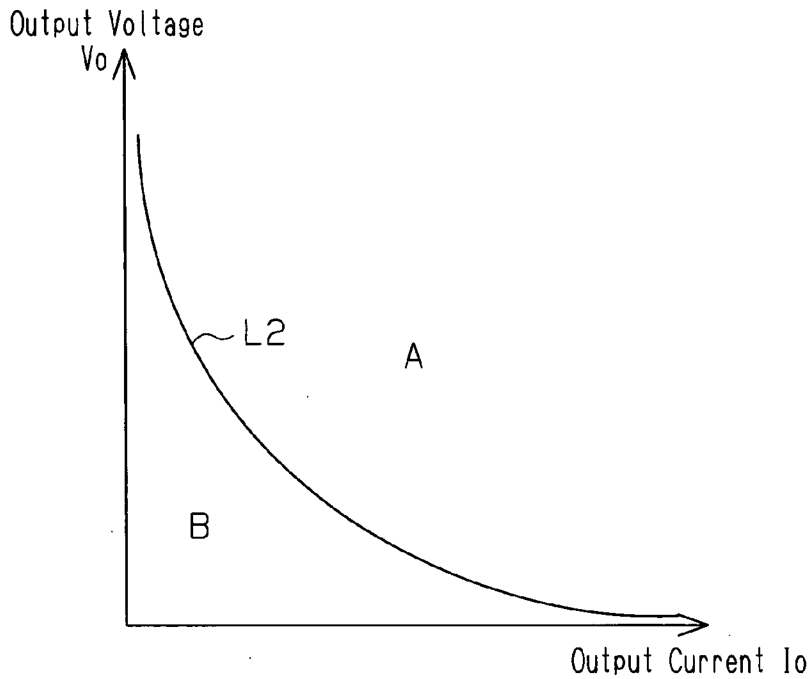

Output Voltage
Vo
L2
A
B
Output Current Io

Fig.5

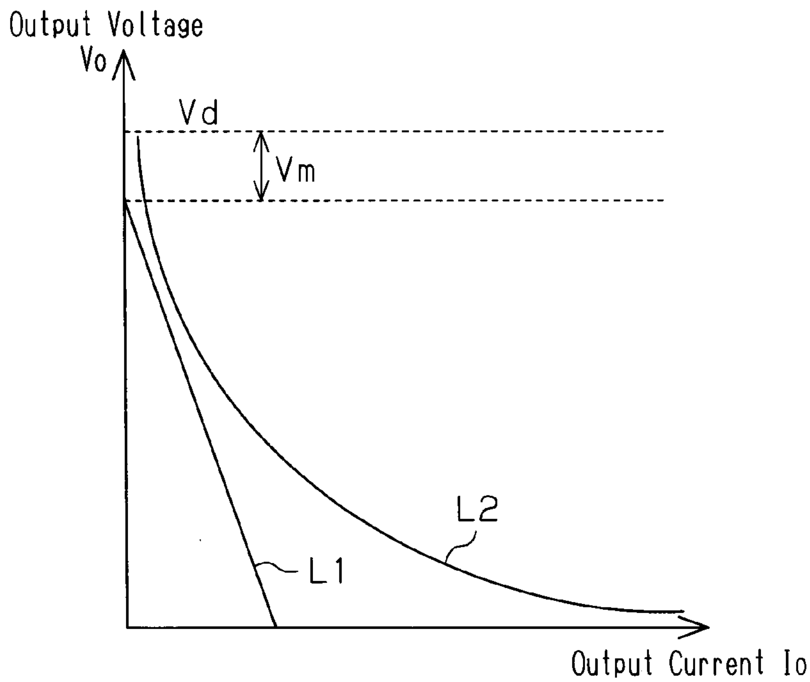

Output Voltage
Vo
Vd
Vm
L2
L1
Output Current Io

Fig.6

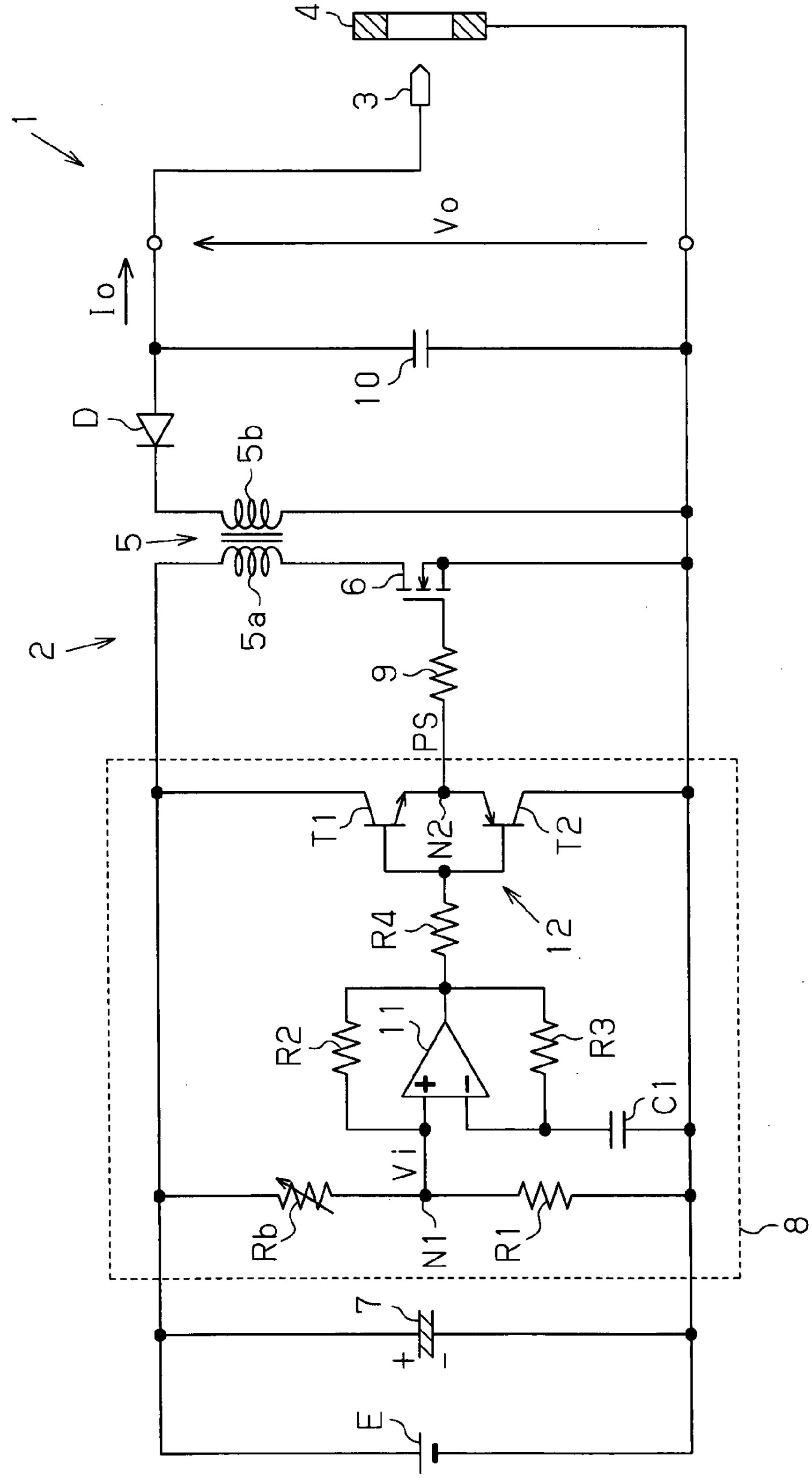
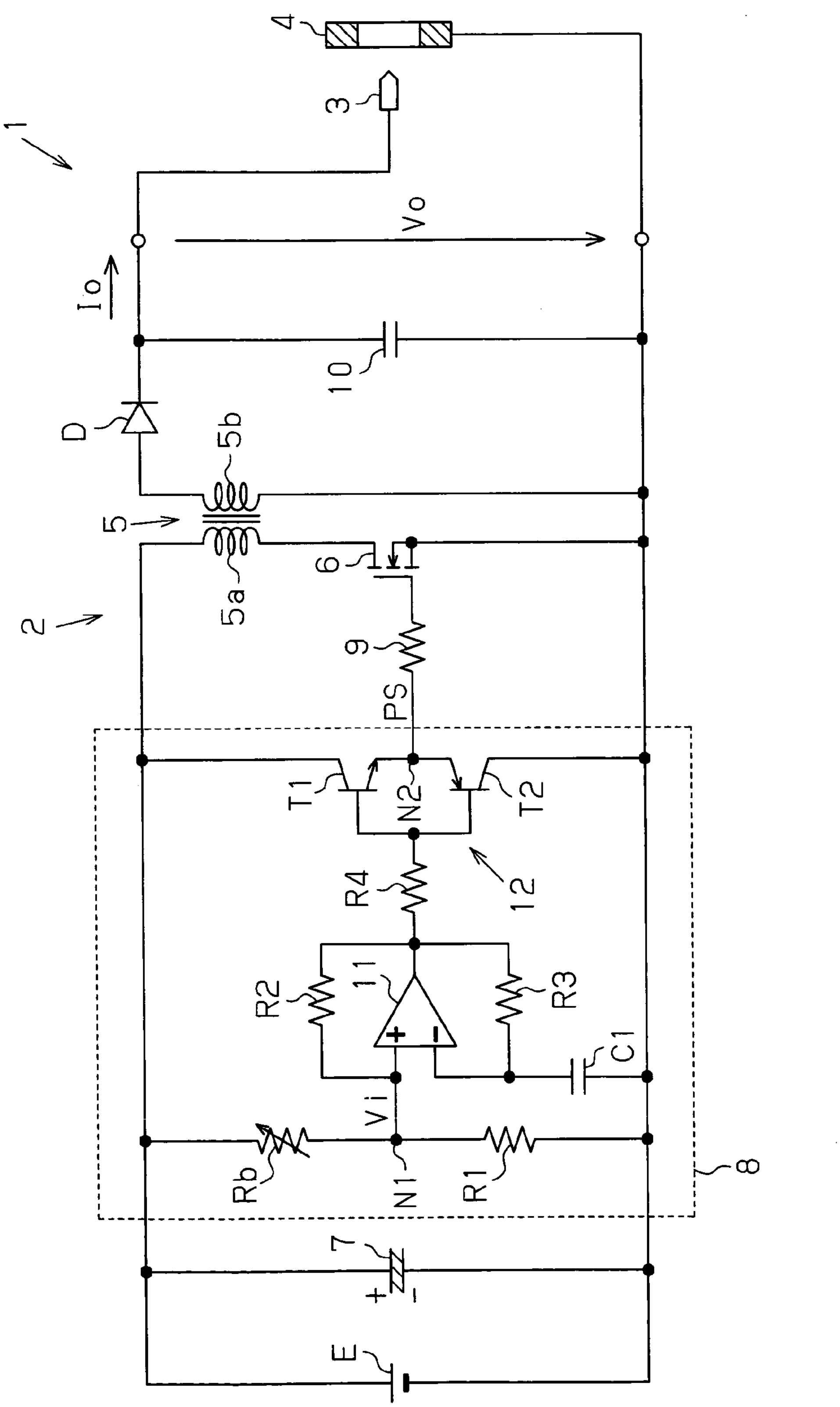


Fig.7



ELECTROSTATIC ATOMIZATION DEVICE

TECHNICAL FIELD

[0001] The present invention relates to an electrostatic atomization device.

BACKGROUND ART

[0002] Japanese Laid-Open Patent Publication Nos. 2006-334503 and 2007-21370 each describe a prior art example of an electrostatic atomization device that generates charged fine water droplets of nanometer size. In a state in which water is supplied to the distal end of a discharge electrode by using capillary action, the electrostatic atomization device applies high voltage to the discharge electrode. When high voltage is applied to the discharge electrode, the water supplied to the discharge electrode is charged. This results in repetitive occurrence of Rayleigh breakups and causes electrostatic atomization of the water. As a result, the electrostatic atomization device generates charged fine water droplets of nanometer size.

[0003] In such a type of electrostatic atomization device, a self-oscillating flyback ringing choke converter (RCC) is used as a switching power supply. The self-oscillating flyback RCC self-oscillates a power MOSFET with a feedback coil wound around a high voltage generation transformer. Accordingly, the self-oscillating flyback RCC does not require a separate oscillation circuit or the like and allows for a relatively small circuit scale. Thus, the self-oscillating flyback RCC is often used in electrostatic atomization devices. Further, for the output control of a self-oscillating flyback RCC, feedback control is often employed to readily activate a turn-off switch for the power MOSFET in accordance with the output voltage.

[0004] In an electrostatic atomization device, air discharge occurs when the voltage in a no-load state is too high. In such a case, the electrostatic atomization device may not shift to electrostatic atomization. Further, when too much water collects on the discharge electrode, excessive current flows to the discharge electrode. In such a case, a large amount of ozone is generated, and the ozone concentration becomes high.

[0005] To prevent such a problem, it is desirable that a high voltage generation circuit have power supply load characteristics that suppress the generation of a large amount of ozone by lowering the voltage applied to the discharge electrode when excessive current flows.

DISCLOSURE OF THE INVENTION

[0006] It is an object of the present invention to provide an electrostatic atomization device that prevents air discharge and the generation of a large amount of ozone with low cost and without the need for performing feedback control.

[0007] One aspect of the present invention is an electrostatic atomization device provided with a transformer including a primary coil and a secondary coil. A switching element is connected in series to the primary coil of the transformer. A switching element drive circuit provides the switching element with a pulse signal to perform a switching operation with the switching element and generate high voltage from the secondary coil of the transformer. A discharge unit including a discharge electrode performs electrostatic atomization on liquid supplied to the discharge electrode to generate charged fine liquid droplets when the high voltage generated by the secondary coil is applied to the discharge electrode. The switching element drive circuit generates a pulse signal having an oscillation frequency set so that the transformer has drooping characteristics that prevent air discharge from occurring between the discharge electrode and ground and prevent ozone having a predetermined concentration or greater when the liquid undergoes electrostatic atomization even when load on the discharge unit varies.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. **1** is an electric circuit diagram of an electrostatic atomization device according to one embodiment of the present invention;

[0009] FIG. **2** is a graph showing the drooping characteristics of a transformer;

[0010] FIG. **3** is a graph showing the relationship of an air discharge voltage and the drooping characteristics of the transformer;

[0011] FIG. **4** is a graph showing the relationship of a regulated generated ozone amount with respect to the output voltage and output current of the transformer;

[0012] FIG. **5** is a graph showing the relationship of the drooping characteristics of the transformer with respect to the air discharge voltage and regulated generated ozone curve in the present embodiment;

[0013] FIG. **6** is a detailed electric circuit diagram of the present embodiment; and

[0014] FIG. **7** is an electric circuit diagram of an electrostatic atomization device in a further example.

DESCRIPTION OF EMBODIMENTS

[0015] An electrostatic atomization device **1** according to one embodiment of the present invention will now be discussed with reference to the drawings.

[0016] FIG. **1** shows a high voltage generation circuit **2** of the electrostatic atomization device **1**. The high voltage generation circuit **2** applies high voltage between a discharge electrode **3** and ground, namely, a ground electrode **4**, which form a discharge unit arranged in the electrostatic atomization device **1**. The discharge electrode **3** and the ground electrode **4** are spaced apart from each other by a predetermined distance. In a state in which water, serving as liquid, is supplied to the distal end of the discharge electrode **3**, the high voltage generation circuit **2** applies high voltage between the discharge electrode **3** and the ground electrode **4**.

[0017] As a result, Coulomb force locally raises the liquid surface of the water supplied to the distal portion of the discharge electrode **3** into a conical form (Taylor cone). The raised conical form of the water has a distal end at which charge is concentrated. This increases the charge concentration, and the repulsive force of the high concentration charges breaks up and scatters the water. The breakup and scattering (Rayleigh breakup) is repeated and the electrostatic atomization performed to generate a large amount of charged fine water droplets of nanometer size including active species.

[0018] In FIG. **1**, a direct current power supply E, which generates a DC voltage of 12 V, includes a positive terminal and a negative terminal. A series circuit including a primary coil **5***a* of a high voltage generation transformer **5** and a power MOSFET **6**, which serves as a switching element, is connected between the positive and negative terminals of the direct current power supply E. Further, a smoothing electrolytic capacitor **7** is connected between the positive and negative terminals of the direct current power supply E. The direct current power supply E supplies an oscillation circuit **8**, which serves as a switching element drive circuit, with 12 V of operational drive voltage.

[0019] The oscillation circuit **8** is supplied with drive voltage from the direct current power supply E. The oscillation circuit **8** generates a pulse signal PS for activating and deactivating the power MOSFET **6** and provides the pulse signal PS to a gate terminal of the power MOSFET **6** via a resistor **9**.

[0020] The power MOSFET **6** is activated or deactivated when its gate terminal receives the pulse signal PS. The activation and deactivation of the power MOSFET **6** intermittently energizes the primary coil **5***a* of the high voltage generation transformer **5** with the direct current power supply E. As a result, a secondary coil **5***b* of the high voltage generation transformer **5** generates a secondary voltage, which is a high voltage.

[0021] A half-wave rectification circuit including a diode D and a capacitor **10** is connected between the two terminals of the secondary coil **5***b*. The half-wave rectification circuit rectifies the high secondary voltage from the secondary coil **5***b* and generates an output voltage Vo, which has a high voltage (in the present embodiment, 5 kV).

[0022] In the electrostatic atomization device **1**, when the amount of water on the discharge electrode **3** becomes small, it is known that the Taylor cone becomes small and the distance from the distal end of the Taylor cone to the ground electrode **4** becomes longer thereby decreasing the discharge current (output current Io). In the electrostatic atomization device **1**, when the amount of water on the discharge electrode **3** further decreases, discharging does not occur between the water on the discharge electrode **3** and the ground electrode **4**. This results in a discharge (air discharge) occurring between the discharge electrode **3** and the ground electrode **4**. Thus, electrostatic atomization is not performed.

[0023] On the other hand, when the amount of water on the discharge electrode **3** of the electrostatic atomization device **1** becomes large, it is known that the Taylor cone becomes large and the distance from the distal end of the Taylor cone to the ground electrode **4** becomes shorter thereby increasing the discharge current. In the electrostatic atomization device **1**, when the amount of water on the discharge electrode **3** further increases, the distance between the ground electrode **4** and water becomes extremely short, and short-circuiting current thereby flows between the ground electrode **4** and the water. Thus, mist having the desired droplet diameter cannot be obtained. Further, a large amount of ozone is generated. This increases the ozone concentration.

[0024] Accordingly, air discharge must be prevented. Further, the generation of a large amount of ozone must be prevented when too much water collects on the discharge electrode **3** and excessive current flows. In other words, the output voltage Vo must be lower than a voltage at which air discharge occurs (air discharge voltage). Further, the output voltage Vo must be decreased when the flow of the output current Io is excessive so that the ozone concentration does not become high.

[0025] To satisfy these requirements, the electrostatic atomization device of the present embodiment sets the output voltage Vo output from the secondary coil **5***b* of the transformer **5** so as to prevent air discharge and keep the amount of generated ozone less than or equal to the regulated amount regardless of the amount of water on the discharge electrode **3**. The output voltage Vo is set in accordance with the oscillation frequency and pulse width (activation time) of the pulse signal PS provided from the oscillation circuit **8** to the gate terminal of the power MOSFET **6**.

[0026] In detail, the high voltage generation transformer **5** includes a large stray capacitance. Accordingly, the efficiency of the high voltage generation transformer **5** decreases when the oscillation frequency increases. Thus, due to the drooping characteristics of the high voltage generation transformer **5** shown in FIG. **2**, in which the output voltage Vo decreases as the load current (output current Io) increases, the output voltage Vo does not increase when the output current Io is high.

[0027] In the present embodiment, the gradient of the drooping characteristics is varied in accordance with the oscillation frequency so as not to generate the output voltage Vo that generates more ozone than the regulated amount. In other words, the drooping characteristic line L**1** shown in FIG. **2** is varied in accordance with the oscillation frequency and pulse width (activation time) of the pulse signal PS output from the oscillation circuit **8**.

[0028] In detail, to prevent air discharge, in the drooping characteristics of the high voltage generation transformer **5**, the output voltage Vo must be set to be at least less than or equal to an air discharge voltage Vd, for example, as shown in FIG. **3**. Thus, a margin voltage Vm is set taking into consideration variations and independent differences of the high voltage generation transformer **5**. In the drooping characteristics of the high voltage generation transformer **5**, the output voltage Vo is set to a voltage obtained by subtracting the margin voltage Vm from the air discharge voltage Vd.

[0029] The drooping characteristics shown in FIG. **3** are obtained by setting the oscillation frequency and pulse width (activation time) of the pulse signal PS output from the oscillation circuit **8**.

[0030] FIG. **4** shows a regulated ozone amount generation curve L**2**. The regulated ozone amount generation curve L**2** indicates the output voltage Vo and current Io, namely, power, for a predetermined tolerable ozone generation amount. More specifically, as shown in FIG. **4**, with the regulated ozone amount generation curve L**2** forming a boundary, the ozone generation amount is greater than or equal to the regulated amount in range A, and the ozone generation amount is less than the regulated amount in range B. Hence, the drooping characteristics (drooping characteristic line L**1**) of the high voltage generation transformer **5** must be included in range B.

[0031] Accordingly, in the drooping characteristics (drooping characteristic line L**1**) of the high voltage generation transformer **5** that avoids air discharge and prevents the ozone generation amount from being greater than or equal to the regulated amount, for example, as shown in FIG. **5**, the output voltage Vo must at least be greater than or equal to the air discharge voltage Vd (including margin voltage Vm), and the power must be less than or equal to the power set by the regulated ozone amount generation curve L**2**. The drooping characteristics (drooping characteristic line L**1**) shown in FIG. **5** is obtained by setting the oscillation frequency of the pulse signal PS output from the oscillation frequency.

[0032] In the present embodiment, the drooping characteristics for the high voltage generation transformer **5** shown in FIG. **5** are obtained through tests, experiments, and calculations. Further, in the present embodiment, the oscillation frequency and pulse width (activation time) of the pulse signal PS output from the oscillation circuit **8** are set so that the electrostatic atomization device **1** is operated based on the drooping characteristics shown in FIG. **5**.

[0033] Accordingly, the oscillation circuit **8** provides the power MOSFET **6** with the pulse signal PS, which has the oscillation frequency and pulse width (activation time) shown in FIG. **5**, to activate and deactivate the power MOSFET.

[0034] In this manner, the electrostatic atomization device **1** prevents air discharge and the generation of a large amount of ozone regardless of the amount of water on the discharge electrode **3** that varies depending on the situation.

[0035] In addition, there is no need to detect the output voltage Vo or output current Io and feedback-control the power MOSFET based on such detected output voltage Vo or output current Io. Accordingly, there is no need for a complicated and expensive circuit that feedback-controls the output of the electrostatic atomization device **1**. Thus, the electrostatic atomization device **1** may be manufactured with less components and lower costs.

[0036] The high voltage generation circuit **2** of the electrostatic atomization device **1** will now be discussed with reference to FIG. **6**.

[0037] As shown in FIG. **6**, the oscillation circuit **8** includes a comparator **11**. The comparator **11** includes a positive input terminal (non-inverting input terminal) supplied with a divisional voltage of a series circuit including a variable resistor Rb and a first resistor R**1**, which are connected between the positive terminal and negative terminal of the direct current power supply E. That is, the series circuit, in which the variable resistor Rb and the first resistor R**1** are connected in series, is connected between the positive terminal and negative terminal of the direct current power supply E, and the voltage (divisional voltage) at a connection point (node N**1**) of the variable resistor Rb and the first resistor R**1** is supplied as an input voltage Vi to the positive input terminal of the comparator **11**.

[0038] Further, the positive input terminal of the comparator **11** is connected via a second resistor R**2** to the output terminal of the comparator **11**. A negative input terminal (inverting input terminal) of the comparator **11** is connected via a capacitor C**1** to the negative terminal of the direct current power supply E. Further, the negative input terminal of the comparator **11** is connected via a third resistor R**3** to the output terminal of the comparator **11**.

[0039] The oscillation circuit **8** using the comparator **11** generates at its output terminal the pulse signal PS, which has a rectangular wave and includes an oscillation frequency determined by the resistance of the third resistance R**3** and the capacitance of the capacitor C**1**. Adjustment of the resistance of the variable resistor Rb adjusts the pulse width (activation time), or frequency, of the pulse signal PS.

[0040] In the present embodiment, the frequency and pulse width (activation time) of the pulse signal PS are predetermined. That is, as described above, the drooping characteristics of the voltage generation transformer **5** shown in FIG. **5** are obtained beforehand through tests, experiments, and calculations. Further, the oscillation frequency and pulse width (activation time) of the pulse signal PS output from the oscillation circuit **8** (comparator **11**) are set so that the electrostatic atomization device **1** operates in accordance with the drooping characteristics shown in FIG. **5**. In other words, the oscillation frequency and pulse width (activation time) of the pulse signal PS are set so as to generate the output voltage Vo that is less than or equal to the voltage at which air discharge occurs (air discharge voltage) and so as to decrease the output voltage Vo when excessive output current Io flows to prevent the ozone concentration from becoming high.

[0041] In the present embodiment, the resistance of the variable resistor Rb is adjusted to easily set the oscillation frequency and pulse width (activation time) of the pulse signal PS. The output terminal of the comparator **11** is connected via a fourth resistor R**4** to a totem pole drive circuit **12**. The totem pole drive circuit **12** includes an NPN transistor T**1** and a PNP transistor T**2**. The base terminals of the two transistors T**1** and T**2** are connected via the fourth resistor R**4** to the output terminal of the comparator **11**.

[0042] The collector terminal of the NPN transistor T**1** is connected to the positive terminal of the direct current power supply E, and the collector terminal of the PNP transistor T**2** is connected to the negative terminal of the direct current power supply E. The emitter terminals of the two transistors T**1** and T**2** are connected to each other. A connection point (node N**2**) of the two transistors T**1** and T**2** are connected via the resistor **9** to the gate terminal of the power MOSFET **6**.

[0043] When the pulse signal PS output from the output terminal of the comparator **11** has a high level, the NPN transistor T**1** is activated and the PNP transistor T**2** is deactivated. As a result, voltage having 12 V (high level) is applied to the gate terminal of the power MOSFET **6**. This activates the power MOSFET **6**. Further, the direct current power supply E energizes the primary coil **5***a* of the high voltage generation transformer **5**.

[0044] On the other hand, when the pulse signal PS output from the output terminal of the comparator **11** has a low level (the pulse signal PS is lost), the NPN transistor T**1** is deactivated and the PNP transistor T**2** is activated. As a result, voltage having 0 V (low level) is applied to the gate terminal of the power MOSFET **6**. This activates the power MOSFET **6** and de-energizes the primary coil **5***a* of the high voltage generation transformer **5**.

[0045] The power MOSFET **6** is activated and deactivated in accordance with the pulse signal PS output from the comparator **11**. This intermittently energizes the primary coil **5***a* of the high voltage generation transformer **5**. As a result, a high secondary voltage is generated at the secondary coil **5***b* of the high voltage generation transformer **5**.

[0046] The half-wave rectification circuit, which includes the diode D and the capacitor **10**, rectifies the high secondary voltage generated by the secondary coil **5***b*. This applies the output voltage Vo of 5 kV between the discharge electrode **3** and the ground electrode **4**.

[0047] In the present embodiment, the oscillation frequency and pulse width (activation time) of the pulse signal PS generated by the comparator **11** are set to obtain the drooping characteristics of the high voltage generation transformer **5**, in which the output voltage Vo is at least less than or equal to the air discharge voltage and the power is less than or equal to the power of the regulated ozone amount generation curve L**2**. This avoids the occurrence of air discharge and prevents the ozone generation amount from becoming greater than or equal to the regulated amount.

[0048] Thus, the electrostatic atomization device **1** generates output voltage Vo that is less than or equal to the voltage at which air discharge occurs (air discharge voltage Vd) without performing complicated feedback control and decreases the output voltage Vo when excessive current Io flows. As a result, the electrostatic atomization device **1** prevents the occurrence of air discharge and the generation of a large amount of ozone regardless of the amount of water on the discharge electrode **3** that varies depending on the situation.

[0049] Additionally, in the present embodiment, the oscillation circuit **8** is formed by the comparator **11**. Thus, with a simple circuit configuration, the pulse signal that is generated has an oscillation frequency that is constantly stable in comparison with the conventional LC oscillation circuit or the like.

[0050] Further, in the present embodiment, the oscillation frequency of the pulse signal PS is easily adjusted just by adjusting the resistance of the variable resistor Rb. This easily obtains the desired drooping characteristics for the high voltage generation transformer **5**.

[0051] It should be apparent to those skilled in the art that the present invention may be embodied in many other specific forms without departing from the spirit or scope of the invention. Particularly, it should be understood that the present invention may be embodied in the following forms.

[0052] In the above-discussed embodiment, the cathode of the diode D arranged in the rectification circuit is connected to the secondary coil **5*b*** of the transformer **5**. However, as shown in FIG. **7**, the cathode of the diode D arranged in the rectification circuit may be connected to the capacitor **10**. That is, when the high voltage generation circuit **2** shown in FIG. **6** applies positive output voltage Vo between the discharge electrode **3** and the ground electrode **4**, the high voltage generation circuit **2** shown in FIG. **7** applies negative output voltage Vo between the discharge electrode **3** and the ground electrode **4**.

[0053] In the above-discussed embodiment, the resistance of the variable resistor Rb connected to the positive input terminal of the comparator **11** is adjusted to adjust the oscillation frequency of the pulse signal PS. That is, the drooping characteristics of the high voltage generation transformer **5** are varied. Instead, for example, the first resistor R**1** may be replaced by a variable resistor or the capacitor C**1** may be replaced by capacitor having a variable capacitance. The resistance of the variable resistor or the capacitance of the variable capacitance capacitor may be changed to adjust the oscillation frequency of the pulse signal PS. Further, at least one of the variable resistor Rb, the variable resistor, and the variable capacitance capacitor may be changed as required to adjust the oscillation frequency of the pulse signal PS.

[0054] In the above-discussed embodiment, the power MOSFET **6** is used as the switching element. However, a bipolar transistor may be used instead as the switching element.

[0055] In the above-discussed embodiment, the half-wave rectification circuit is used to rectify the secondary voltage generated by the secondary coil **5*b***. However, the rectification circuit may be a full-wave rectification circuit.

[0056] In the above-discussed embodiment, the oscillation circuit **8** is operated by the comparator **11**. Instead, another oscillation circuit configured to output a pulse signal that activates and deactivates the switching element may be used.

[0057] In the above-discussed embodiment, the direct current power supply E for 12 V is used. However, for example, a direct current power supply that rectifies commercial power with a full-wave rectification circuit may be used instead.

[0058] In the above-discussed embodiment, the present embodiment is applied to an electrostatic atomization device that generates charged fine water droplets by performing electrostatic atomization on water. However, the present invention may also be applied to an electrostatic atomization device that generates charged fine liquid droplets of nanometer size by atomizing liquid other than water, such as a skin lotion or a chemical.

[0059] In the above-discussed embodiment, the ground electrode **4** is arranged facing toward the discharge electrode **3**. However, the arrangement and location of the ground electrode **4** are not particularly limited. Further, a portion corresponding to the ground electrode **4** may be formed by a housing of the electrostatic atomization device **1**.

[0060] The present examples and embodiments are to be considered as illustrative and not restrictive, and the invention is not to be limited to the details given herein, but may be modified within the scope and equivalence of the appended claims.

1. An electrostatic atomization device comprising:

a transformer including a primary coil and a secondary coil;

a switching element connected in series to the primary coil of the transformer;

a switching element drive circuit that provides the switching element with a pulse signal to perform a switching operation with the switching element and generate high voltage from the secondary coil of the transformer; and

a discharge unit including a discharge electrode, in which the discharge unit performs electrostatic atomization on liquid supplied to the discharge electrode to generate charged fine liquid droplets when the high voltage generated by the secondary coil is applied to the discharge electrode;

wherein the switching element drive circuit generates a pulse signal having an oscillation frequency set so that the transformer has drooping characteristics that prevent air discharge from occurring at the discharge electrode and prevent ozone having a predetermined concentration or greater when the liquid undergoes electrostatic atomization even when load on the discharge unit varies.

2. The electrostatic atomization device according to claim **1**, wherein the discharge unit includes a ground electrode spaced apart by a constant distance from the discharge electrode, the electrostatic atomization device further comprising:

a rectification circuit connected between the secondary coil of the transformer, the discharge electrode, and the ground electrode, in which the rectification circuit rectifies the high voltage generated by the secondary coil and applies the rectified high voltage between the discharge electrode and the ground electrode.

3. The electrostatic atomization device according to claim **1**, wherein the switching element drive circuit includes an oscillation circuit that generates the pulse signal.

4. The electrostatic atomization device according to claim **3**, wherein the oscillation circuit includes a comparator.

5. The electrostatic atomization device according to claim **1**, wherein the switching element drive circuit includes:

a fixed resistor and a variable resistor connected in series;

a comparator having an inverting input terminal, a non-inverting input terminal connected to a node between the fixed resistor and the variable resistor, and an output terminal that outputs the pulse signal; and

a capacitor connected to the inverting input terminal of the comparator;

wherein the oscillation frequency is set by adjusting resistance of the variable resistor.

6. The electrostatic atomization device according to claim **1**, wherein the switching element drive circuit includes:

a first fixed resistor and a second fixed resistor connected in series;

a comparator having an inverting input terminal, a non-inverting input terminal connected to a node between the first fixed resistor and the second fixed resistor, and an output terminal that outputs the pulse signal; and

a variable capacitance capacitor connected to the inverting input terminal of the comparator;

wherein the oscillation frequency is set by adjusting capacitance of the variable capacitance capacitor.

7. The electrostatic atomization device according to claim **1**, wherein the switching element drive circuit includes:

a first variable resistor and a second variable resistor connected in series;

a comparator having an inverting input terminal, a non-inverting input terminal connected to a node between the first variable resistor and the second variable resistor, and an output terminal that outputs the pulse signal; and

a variable capacitance capacitor connected to the inverting input terminal of the comparator;

wherein the oscillation frequency is set by adjusting at least one of resistances of the first and second variable resistors and capacitance of the variable capacitance capacitor.

8. The electrostatic atomization device according to claim **5**, wherein the switching element drive circuit includes:

a totem pole drive circuit connected to the output terminal of the comparator, in which the totem pole drive circuit receives the pulse signal from the comparator, amplifies the pulse signal, and provides the amplified pulse signal to the switching element.

* * * * *