

IONIZER COMPRISING ION DETECTOR

TECHNICAL FIELD

[0001] The present invention relates to an ionizer for generating ions.

BACKGROUND

[0002] Electrostatic charges may be generated in workpieces during manufacturing or assembly processes, causing the workpieces to be electrostatically charged. The electrostatic charges generated may cause undesirable effects. For instance, during the manufacturing or assembly of electronic components, such as semiconductor chips, the electronic portions of jigs may become electrostatically charged due to various reasons. The electrostatic charges may damage the electronic components.

[0003] An ionizer, which may also be referred to as an ion generator or an ion generating apparatus, is typically used to remove the electrostatic charges. A high voltage is applied at a sharp tip of an electrode in the ionizer. The high voltage causes a discharge through the air surrounding the electrode, thus generating a balanced amount of positive and negative ions. A fan or air compressor is then used to blow the ionized air onto the workpiece.

[0004] The tip portion of the electrode tends to be corroded with time due to impingement of high energy ions onto the tip portion. FIG. 1A illustrates the corrosion of the tip portion with time. Electrode 50 is relatively new, while electrode 51 has been used for some time. Electrode 52 has been used for a prolonged period of time.

[0005] In addition to corrosion, the electrode also becomes contaminated due to dust particles present in the environment, as well as nitrides generated during the ionization process. FIGS. 1B – 1D show contamination of an electrode 53 with time when the ionizer with the electrode 53 is continuously used at an air flow rate of 9 litres per minute. FIG. 1B is an initial image of the electrode 53. FIG. 1C shows the image of the electrode 53 after 4 days, while FIG. 1D shows the image of the electrode 53 after 17 days.

[0006] The corrosion and contamination may cause the balance between the positive ions and the negative ions to become skewed as the electrical field around the electrode changes, especially at high flow rates. Corrosion or contamination may also result in a lower rate of ionization of air or a low flow rate of ionized air out of the ionizer. In severe cases, there may

even be no output of ionized air from the ionizer. These may result in situations in which the ionizer is unable to generate sufficient ions to effectively neutralize the electrostatic charges on the workpiece.

SUMMARY

[0007] The invention thus seeks to provide an improved ionizer which is able to determine the condition of the ionization electrode. The determination of the condition of the ionization electrode would allow the user to know when to replace or clean the ionization electrode, thus avoiding or reducing occurrences in which the ionizer is unable to generate sufficient ions to effectively neutralize the electrostatic charges on an object, such as a workpiece.

[0008] Accordingly, the invention provides an ionizer including an ionization chamber, an air inlet coupled to the ionization chamber, and an ionization electrode having a tip portion positioned within the ionization chamber. The ionizer further includes a high voltage generator in electrical connection with the ionization electrode, the high voltage generator operative to apply an ionization voltage to the tip portion to generate ions. The ionizer also includes an output nozzle coupled to the ionization chamber, and an ion detector that is operative to detect the ions generated in the ionization chamber.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The invention will be better understood with reference to the detailed description when considered in conjunction with the non-limiting examples and the accompanying drawings, in which:

FIG. 1A is an image showing the tip portions of three electrodes at different stages of corrosion.

FIG. 1B is an initial image of the electrode.

FIG. 1C shows the image of the electrode after 4 days.

FIG. 1D shows the image of the electrode after 17 days.

FIG. 2 is a perspective view of the ionizer according to an embodiment of the invention.

FIG. 3 is a perspective view of the ionizer shown in FIG. 2 but with a metal cover removed.

FIG. 4 is a cross-sectional side view of the ionizer illustrated in FIG. 2.

FIG. 5 is a side view of an inserter assembly of the ionizer as shown in FIG. 2 separated from a main body of the ionizer.

FIG. 6 is a perspective exploded view of an inserter assembly as shown in FIG. 5.

FIG. 7 is a perspective exploded view of a nozzle assembly of the ionizer shown in FIG. 2, as well as a perspective assembled view of the nozzle assembly.

FIG. 8 illustrates the assembling of a flexible printed circuit with the other portions of the nozzle assembly.

FIG. 9A illustrates the assembling of a metal shielding and an adaptor of the ionizer shown in FIG. 2 to form a shielding assembly.

FIG. 9B shows a flexible printed circuit and a holder of the ionizer shown in FIG. 2 being assembled together to form a flexible printed circuit assembly.

FIG. 9C shows the flexible printed circuit assembly shown in FIG. 9B being assembled with the shielding assembly shown in FIG. 9A.

FIG. 9D shows the structure shown in FIG. 9C being fitted into a nozzle of the ionizer shown in FIG. 2.

FIG. 9E illustrates a portion of the ionizer shown in FIG. 2 including the nozzle assembly and the ionization electrode.

FIG. 10 illustrates ion balance detection used in an embodiment of the invention.

FIG. 11A shows a plot of surface residential voltage (in volts or V) as a function of sensor output (in volts or V) showing an ion-resolution test with surface residential voltage controlled by the ionizer according to an embodiment of the present invention only.

FIG. 11B shows a plot of surface potential (in volts or V) as a function of ion-balance output (in volts or V) at different flow rates.

FIG. 12A shows a plot of surface residential voltage (in volts or V) as a function of ion balance detector output (in millivolts or mV) exhibited by the ionizer according to an embodiment of the present invention with a contaminated electrode.

FIG. 12B shows a plot of ion balance detector output (in millivolts or mV) / surface residential voltage (in volts or V) as a function of time (in seconds) exhibited by the ionizer of FIG. 12A with the contaminated electrode.

FIG. 12C shows an image of the contaminated electrode at a magnification of 50.

FIG. 13A shows a plot of surface residential voltage (in volts or V) as a function of ion balance detector output (in millivolts or mV) exhibited by the ionizer according to an embodiment of the present invention with a clean electrode.

FIG. 13B shows a plot of ion balance detector output (in millivolts or mV) / surface residential voltage (in volts or V) as a function of time (in seconds) exhibited by the ionizer of FIG. 13A with the clean electrode.

FIG. 13C shows an image of the clean electrode at a magnification of 50.

DETAILED DESCRIPTION

[0010] An embodiment of the invention will now be described with reference to FIGS. 2 – 10. Further, FIGS. 11A – 13C relate to data and images of an embodiment of the invention.

[0011] FIG. 2 shows an ionizer with a main body 4 as well as an inserter assembly 3. The inserter assembly 3 is an assembled component which can be attached to the main body 4 to generate ionized air during operation. The main body 4 includes air inlet 1 for receiving air which contains little or no ions, and a nozzle 6 defining an output 7 for ionized air, i.e. air which contains a significant amount of ions. The ionized air may be applied to a workpiece to neutralize the electrostatic charges on the workpiece. An ionizer may alternatively be referred to as an ion generator.

[0012] The main body 4 includes a metal cover 2. The metal cover 2 is L-shaped and covers a top portion as well as a side portion of the main body 4. The main body 4 further includes grounding point 8 and mounting holes 10 on the metal cover 2. The grounding point 8 serves to ground the ionizer, while the mounting holes 10 allow the ionizer to be mounted to an external structure. The main body additionally includes one or more light-emitting diode (LED) indicators 5. The main body 4 also includes intake hole 9.

[0013] FIG. 3 shows the ionizer of FIG. 2 arranged in an opposite direction, with the inserter assembly 3 visible at the front, and the nozzle 6 at the back. The external metal cover 2 is removed from the main body 4.

[0014] The inserter assembly 3 may be inserted into the main body 4 during operation for generation of ionized air, and may be removed from the main body 4 during maintenance. A locker 11 is used to hold or lock the inserter assembly 3 within the main body 4 when the inserter assembly 3 is inserted into the main body 4. The locker 11 also helps to reduce or prevent air leakage from the ionizer.

[0015] A shielding 16 is also visible in FIG. 3. A tab portion 21d of an ion detector such as a printed circuit, e.g. a flexible printed circuit (FPC) 21, protrudes through a notch or opening 16a of the shielding 16. The main body 4 further includes an ionizer driver and detection board 33, which may also be referred to as a driver and detection circuit. The flexible printed circuit 21 is electrically connected to the ionizer driver and detection board 33 by connecting the tab portion 21d to connection point 34 of the ionizer driver and detection board 33. Further, the ionizer driver and detection board 33 is in electrical connection with the one or more light-emitting diode (LED) indicators 5 shown in FIG. 2. The ionizer driver and detection board 33 is also connected to electrical connector 26, which is positioned below locker 11. The electrical connector 26 receives a cable from an external power supply. Accordingly, the electrical connector 26 electrically connects the ionizer driver and detection board 33 to the external power supply.

[0016] FIG. 4 shows a cross-sectional side view of the ionizer of FIG. 2. The main body 4 includes an ionization chamber 31, and an air channel 27 for supplying compressed air from the air inlet 1 to the ionization chamber 31. The ionization chamber 31 is in fluidic communication with the air inlet 1 via the air channel 27.

[0017] Air with little or no ions from the atmosphere is introduced into the ionization chamber 31 via the air inlet 1. An ionization electrode 14 generates ions by creating a discharge through the air in the ionization chamber 31. The output nozzle 6 is also coupled to the ionization chamber 31 so that the output nozzle 6 is in fluidic communication with the ionization chamber 31. The flexible printed circuit 21 is arranged to surround at least a portion of the ionization chamber 31 when in use and determines the condition of the ionization electrode 14 by determining the relative numbers of positive and negative ions present in the air that flows through the detection area 32 of the ionizer.

[0018] The ionizer is an alternating current (AC) ionizer. An ionization electrode 14 which is not contaminated or corroded would typically generate about equal numbers of positive ions and negative ions, as the ionization voltage alternates between negative and positive. The ionization voltage may alternate between negative and positive at 60 times or more per second. When the ionization electrode 14 becomes contaminated or corroded, the ratio of positive ions to negative ions would fall outside a predetermined range, thus triggering the one or more light-emitting diode (LED) indicators 5 via the flexible printed circuit 21 and the ionizer driver and detection board 33. In other words, the ionizer driver and

detection board 33 is operative to control the one or more indicators 5 to provide a warning when a ratio of positive ions to negative ions is out of a predetermined range. Accordingly, a user would be able to know when to clean or replace the ionization electrode 14.

[0019] AC ionizers have advantages over direct current (DC) ionizers. For instance, an AC ionizer would only need a single ionization electrode, while a DC ionizer would require two ionization electrodes. As the AC ionizer requires only a single ionization electrode, the AC ionizer may be made more compact. Also, an AC ionizer may generate balanced ions, i.e. equal amounts of positive and negative ions using a dielectric barrier discharge and an appropriate nozzle structure. An AC ionizer may however, require a rather high flow rate to blow the generated ions onto the workpiece, as the AC electric field would tend to impede the transmission of the ions. The AC ionizer may be a gun type ionizer, which uses compressed air to blow the ions to the target area on the workpiece.

[0020] The main body 4 further includes a printed circuit board chamber 24 for holding the ionizer driver and detection board 33. The printed circuit board chamber 24 is mounted by mounting holes 25. As highlighted earlier, the ionizer driver and detection board 33 is powered by an external power supply through electrical connector 26.

[0021] The inserter assembly 3 further includes a copper tube 12 electrically connected to the ionization electrode 14 at an end of the copper tube 12. The ionization electrode 14 and the copper tube 12 are held by a locker 15. The locker 15 is a tubular structure having a channel. The ionization electrode 14 is inserted into the channel through a first opening on a side of the locker 15, and one end of the copper tube 12 is inserted into the channel through a second opening on the other side of the locker 15 so that the copper tube 12 electrically contacts the ionization electrode 14. The ionization electrode 14 may be soldered to the copper tube 12. The soldering of the ionization electrode 14 to the copper tube 12 may preclude the user from changing only the ionization electrode 14. Should the user wish to change the ionization electrode 14, he should replace the entire inserter assembly 3. Another opposing end of the copper tube 12 is also electrically connected to a high voltage generator such as transformer 30. Accordingly, the copper tube 12 electrically connects the transformer 30 and the ionization electrode 14.

[0022] The transformer 30 is electrically coupled to an external power supply during operation. The external power supply may be the same power supply used for powering the ionizer driver and detection board 33 or may be a separate power supply. The transformer 30

receives a supply voltage provided by the external power supply via a contact pole 13, and based on the supply voltage, generates an ionization voltage higher than the supply voltage at the ionization electrode 14. The transformer 30 generates the ionization voltage for creating a discharge through the air via the tip portion of the ionization electrode 14. The mounting hole 28 is used to mount the contact pole 13. When the tip portion of the ionization electrode 14 is at the ionization voltage, an electric discharge from the tip portion would ionize the air surrounding the ionization electrode 14 in the ionization chamber 31

[0023] The ionization chamber 31 may be formed by a shielding 16 and an isolation ring 17. The shielding 16 is fitted to an adaptor 20, which may be alternatively referred to as an air channel wall. The adaptor 20 may be made of a plastic material, and defines the intake hole 9. The flexible printed circuit 21 is held between the holder 18 and isolation ring 17.

[0024] FIG. 5 shows the inserter assembly 3 being separated from the main body 4. As evident in FIG. 5, the inserter assembly 3 includes the ionization electrode 14 and locker 15. The main body 4 includes the air inlet 1, metal cover 2, one or more LED indicators 5, nozzle 6 defining the output 7, grounding point 8, mounting holes 10, locker 11 and suction hole 23. The air inlet 1 is coupled to the suction hole 23, which helps to extract air from the atmosphere into the ionizer. The suction hole 23 is aligned with an intake hole 9 of adaptor 20 shown in FIG. 4.

[0025] The inserter assembly 3 is detachably insertable into the main body 4. The inserter assembly 3 is attached to the main body 4 during operation for generation of ionized air, but may be detached from the main body 4 during maintenance for replacement or for cleaning of the inserter assembly 3. The inserter assembly 3 may be inserted into the inserter chamber 29 from the back of the main body 4 as shown in FIG. 5. When the inserter assembly 3 is fully inserted into the inserter chamber 29 of the main body 4, the tip portion of the ionization electrode 14 protrudes into the ionization chamber 31. In other words, the tip portion of the ionization electrode 14 is positioned within the ionization chamber 31 during operation for generation of ionized air. The inserter assembly 3 is held in place inside the inserter chamber 29 by locker 11. After the inserter assembly 3 is fully inserted into the inserter chamber 29, the locker 11 is turned in one direction so as to lock the inserter assembly 3 in place. During removal of the inserter assembly 3, the locker 11 may be turned in an opposing direction for unlocking. The inserter assembly 3 may then be removed from the main body 4.

[0026] FIG. 6 is a perspective exploded view of an inserter assembly 3. In addition to the ionization electrode 14 and locker 15, the inserter assembly 3 includes a transformer 30, and a copper tube 12 electrically connecting the transformer 30 to the ionization electrode 14.

[0027] The transformer 30 is soldered onto a transformer holder printed circuit board 3a. An upper cover 3b is fitted to an upper surface of the transformer holder printed circuit board 3a and a lower cover 3c is fitted to a lower surface of the transformer holder printed circuit board 3a. The locker 15 is held by an opening formed by the upper cover 3b and the lower cover 3c when the upper cover 3b and the lower cover 3c are fitted to the transformer holder printed circuit board 3a. The locker 15 has one or more grooves to receive the upper cover 3b and the lower cover 3c, so that the locker 15 may be clipped onto the upper cover 3b and the lower cover 3c. The locker 15 further has an O-ring at the outer surface of the locker 15 to help seal the opening.

[0028] The upper portion of FIG. 7 illustrates a perspective exploded view of the nozzle assembly of the ionizer shown in FIG. 2, while the lower portion of FIG. 7 illustrates a perspective assembled view of the nozzle assembly. The nozzle assembly includes nozzle 6, shielding 16, isolation ring 17, holder 18, adaptor 20 and flexible printed circuit 21. When the nozzle assembly is assembled, a tab portion 21d of the flexible printed circuit protrudes through the notch or opening 16a of shielding 16 for connecting with the ionizer driver and detection board 33. The ionization chamber 31 shown in FIG. 4 is formed by the shielding 16 and isolation ring 17. The shielding 16 is fitted to the adaptor 20. The adaptor 20, the shielding 16 and the isolation ring 17 are hollow tubular structures. When assembled together, the tubular isolation ring 17 is held in the hollow of the shielding 16. The ionization electrode 14 extends through a channel of the adaptor 20 as shown in FIG. 4 into the ionization chamber 31 defined at the sides by the inner walls of the tubular isolation ring 17.

[0029] FIG. 8 illustrates the assembling of the flexible printed circuit 21 with the other portions of the nozzle assembly.

[0030] The flexible printed circuit 21 is sandwiched between the isolation ring 17 and holder 18. The flexible printed circuit 21 is wrapped or arranged around an outer tubular surface of the isolation ring 17, and is prevented from sliding down the isolation ring 17 by a flange 17a of the isolation ring 17, as shown in the lower portion of FIG. 8. The length y of the flexible printed circuit 21 is greater than a length x of the outer tubular surface of the isolation ring 17 so that at least a portion of the flexible printed circuit 21 is exposed to

ionized air from the ionization chamber 31 during operation of the ionizer. The portion of the flexible printed circuit 21 that is exposed defines the detection area 32. The flexible nature of the printed circuit allows the flexible printed circuit 21 to be wrapped around the outer surface of the isolation ring 17.

[0031] The flexible printed circuit 21 includes a flexible substrate 21a, which may include a material such as polyimide (PI). The substrate 21a may alternatively include any other material suitable for making printed circuit boards, and which are sufficiently flexible. The flexible printed circuit 21 further includes a printed first electrode 21b and a printed second electrode 21c that is separate from the printed first electrode 21b. The printed first electrode 21b and the printed second electrode 21c form an interdigitated or cross-fingered electrode structure, as illustrated in the upper portion of FIG. 8. The flexible printed circuit 21 may be arranged around the isolation ring 17 such that the fingers of electrodes 21b, 21c extend substantially parallel to the axis of the channel defined by the isolation ring as shown in 800a of FIG. 8. Alternatively, the flexible printed circuit 21 may be arranged around the isolation ring 17 such that the fingers of the electrodes, 21b, 21c extend along the circumference of the channel defined by the isolation ring 17, and concentrically around the axis of the channel, as shown in 800b. The flexible printed circuit 21 also includes a protruding tab portion 21d.

[0032] The surface area of the printed first electrode 21b and the surface area of the printed second electrode 21c are substantially equal and symmetrical. The first electrode 21b and the second electrode 21c also have similar shapes. When the flexible printed circuit 21 is wrapped around the isolation ring 17, a surface area of the portion of the printed first electrode 21b exposed to the ions generated in the ionization chamber 31 is substantially the same as a surface area of the portion of the printed second electrode 21c exposed to the ions generated in the ionization chamber 31. For instance, in each of configurations 800a and 800b, the surface area of the first electrode 21b exposed to ionized air is about the same as the surface area of the second electrode 21c exposed to ionized air. This is beneficial for repeatability since the orientation at which the ions enter the detection area 32 does not matter.

[0033] The flexible printed circuit 21 may be directly connected to the ionizer driver and detection board 33 through tab portion 21d. The first electrode 21b and the second electrode 21c may extend to the tab portion 21d. The first electrode 21b and the second electrode 21c may thus be directly connected to the ionizer driver and detection board 33. In other words,

the flexible printed circuit 21 also performs the function of a cable. The flexible and thin nature of the flexible printed circuit 21 allows it to occupy very little space, and also allows it to be easily bent towards a connection point 34 of the ionizer driver and detection board 33.

[0034] Current printed circuit board (PCB) technology allows the flexible printed circuit 21 to be designed with the desired layout, structure and/or shape accurately and precisely. The flexible printed circuit 21 occupies little space between the holder 18 and the isolation ring 17 and does not hinder the passage of ionized air out of the ionizer. The flexible printed circuit 21 also allows the inner surfaces of the ionization chamber 31 and/or nozzle 6 to be relatively smoother as compared to alternative means of detection, thus increasing the velocity of the ionized air out of the ionizer. The lifetime of the ions is limited, and a smooth passage of the ions out of the ionizer onto the workpiece would increase the effectiveness of the ionizer.

[0035] The flexible printed circuit 21, the ionizer driver and detection board 33, and the LED indicator 5 form the ion-balance detection sensor, which serves to monitor the ion balance of the ions generated by the ionizer, and to alert the user if the balance is not achieved. Therefore, the sensor helps the ionizer to work within the desired specification.

[0036] FIGS. 9A-9D provide more details of the assembling of the nozzle assembly. In FIG. 9A, the shielding 16 (with the notch or opening 16a) is fitted with adaptor 20.

[0037] FIG. 9B shows the wrapping of the flexible printed circuit 21 around the isolation ring 17 (with flange 17a) as well as the fitting of holder 18 to the isolation ring 17 so that the holder 18 covers the flexible printed circuit 21. The holder 18 is used to hold the flexible printed circuit 21 so that the flexible printed circuit 21 stays wrapped around the isolation ring 17. The holder 18 may be fitted to isolation ring 17 such that the outer surface of the holder 18 is substantially flush with an outer surface of flange 17a. The holder 18 further includes a notch or opening 18a for the tab portion 21d to pass through from the interior of the holder 18 to the exterior of the holder 18.

[0038] FIG. 9C shows an end of the assembly in FIG. 9B fitted to the assembly in FIG. 9A. The hollow tubular shielding 16 is fitted to the hollow tubular isolation ring 17. The shielding 16 has a notch or opening 16a for the tab portion 21d to pass through. The notch or opening 18a of the holder 18 may be aligned with the notch or opening 16a of the shielding 16 when the holder 18 is inserted into the shielding 16. A nozzle 6 is fitted to another end of the assembly of FIG. 9B, as illustrated in FIG. 9D.

[0039] The tab portion 21d of the flexible printed circuit 21 passes through the opening or notch 16a on the shielding 16, as well as the opening or notch 18a on the holder 18, thus allowing the first electrode 21b and the second electrode 21c to be connected to the ionizer driver and detection board 33.

[0040] FIG. 9E shows a magnified view of the portion of the nozzle assembly and the ionization electrode 14 during operation. The ionization electrode 14 is held by locker 15, and is inserted through a channel of the adaptor 20 so that the tip portion of the ionization electrode 14 protrudes into the ionization chamber 31, which is defined by the hollow tubular isolation ring 17. Adaptor 20 also defines intake hole 9. The flexible printed circuit 21 is wrapped around the isolation ring 17, with a portion not covered by the isolation ring 17 and exposed to the ionization chamber 31. The flexible printed circuit 21 is held by the holder 18. A nozzle 6 is fitted to the holder 18.

[0041] During operation, the first electrode 21b may be biased with a biasing voltage of a first polarity, while the second electrode 21c may be biased with a biasing voltage of a second polarity opposite to the first polarity. FIG. 10 illustrates the working principles of the flexible printed circuit 21. For instance, the first electrode 21b may be biased with a negative biasing voltage, while the second electrode 21c may be biased with a positive biasing voltage. Some positive ions from the ion source, i.e. ionization electrode 14, would be attracted to the negatively biased first electrode 21b, while some negative ions from the ion source 14 would be attracted to the positively biased second electrode 21c. The number of positive ions attracted to the negatively biased electrode 21b is proportional to the number of positive ions generated, and the number of negative ions attracted to the positively biased electrode 21c is proportional to the number of negative ions generated. The ions that are not attracted would continue to be blown towards an object 35, e.g. a workpiece. The ionizer driver and detection board 33 determines the change in potential difference between the first electrode 21b, and the second electrode 21c over time, thereby determining the relative change between the number of positive ions and the number of negative ions generated by the ionization electrode 14 over time. The relative change between the number of positive ions and the number of negative ions over time may be calculated by using a suitable formula. When the potential difference goes beyond a predetermined range, the ionizer driver and detection board 33 would trigger the LED indicator 5 to alert the user.

[0042] FIG. 11A shows a plot 1100a of surface residential voltage (in volts or V) as a function of sensor output (in volts or V) showing an ion-resolution test with surface residential voltage controlled by the ionizer only. The dashed lines indicate the range of surface residential voltages exhibited by the sensor in the ionizer. The surface residential voltages may have a positive or negative bias depending on the relative number of positive ions attracted to the negatively biased electrode 21b and the number of negative ions attracted to the positively biased electrode 21c. FIG. 11A shows that the sensor would be able to achieve a detection resolution $\pm 4V$. FIG. 11B shows a plot 1100b of surface potential (in volts or V) as a function of ion-balance output (in volts or V) at different flow rates. FIG. 11B shows that the ion-balance is independent of the ionizer, and has minimal relationship with flow rate.

[0043] FIG. 12A shows a plot 1200a of surface residential voltage (in volts or V) as a function of ion balance detector output (in millivolts or mV) exhibited by the ionizer with a contaminated electrode. FIG. 12B shows a plot 1200b of ion balance detector output (in millivolts or mV) / surface residential voltage (in volts or V) as a function of time (in seconds) exhibited by the ionizer with the contaminated electrode. 60 represents the variation of the ion balance detector output with time, while 61 represents the variation of surface residential voltage with time. The ion balance trigger level is set at +100 mV and -100 mV, when the specification of surface residential voltage is above +10 V or is below -10 V. In other words, the indicator would be triggered if the ion balance output voltage exceeds +100 mV or falls below -100mV, when the specification of surface residential voltage is above +10 V or is below -10 V.

[0044] FIG. 12C shows an image of the contaminated electrode 62 at a magnification of 50.

[0045] FIG. 13A shows a plot 1300a of surface residential voltage (in volts or V) as a function of ion balance detector output (in millivolts or mV) exhibited by the ionizer with a clean electrode. FIG. 13B shows a plot 1300b of ion balance detector output (in millivolts or mV) / surface residential voltage (in volts or V) as a function of time (in seconds) exhibited by the ionizer with the clean electrode. 64 represents the variation of the ion balance detector output with time, while 65 represents the variation of surface residential voltage with time. The indicator would be triggered if the ion balance output voltage exceeds +100 mV or falls

below -100mV, when the specification of surface residential voltage is between -10 V and +10V.

[0046] FIG. 13C shows an image of the clean electrode 66 at a magnification of 50.

[0047] While the invention has been particularly shown and described with reference to specific embodiments, it should be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention as defined by the appended claims. The scope of the invention is thus indicated by the appended claims and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced.

CLAIMS

1. An ionizer comprising:
 - an ionization chamber;
 - an air inlet coupled to the ionization chamber;
 - an ionization electrode having a tip portion positioned within the ionization chamber;
 - a high voltage generator in electrical connection with the ionization electrode, the high voltage generator being operative to apply an ionization voltage to the tip portion to generate ions;
 - an output nozzle coupled to the ionization chamber; and
 - an ion detector that is operative to detect the ions generated in the ionization chamber;
 - wherein the ion detector comprises a flexible printed circuit arranged to surround at least a portion of the ionization chamber.
2. The ionizer according to claim 1, further comprising:
 - a hollow tubular isolation ring locatable in the ionization chamber;
 - wherein the printed circuit is arranged around the tubular isolation ring.
3. The ionizer according to claim 1, further comprising:
 - a driver and detection circuit in electrical connection with the ion detector; and
 - one or more indicators in electrical connection with the driver and detection circuit;
 - wherein the driver and detection circuit is electrically connected to the one or more indicators to provide a warning when a ratio of positive ions to negative ions is outside a predetermined range.
4. The ionizer according to claim 1,
 - wherein the printed circuit comprises:
 - a substrate; and
 - a first electrode, and a second electrode separate from the first electrode, that are formed on the substrate.

5. The ionizer according to claim 4,
wherein the first electrode and the second electrode together form an interdigitated electrode structure.
6. The ionizer according to claim 4,
wherein a surface area of the printed first electrode exposed to the ions is substantially equal to a surface area of the printed second electrode exposed to the ions.
7. The ionizer according to claim 4,
wherein the first electrode is configured to attract positive ions towards the first electrode and the second electrode is operative to attract negative ions towards the second electrode.
8. The ionizer according to claim 1,
wherein the high voltage generator and the ionization electrode are comprised in an inserter assembly which is detachably insertable with respect to the ionization chamber, the inserter assembly further comprising:
an electrically-conducting tube connecting the high voltage generator and the ionization electrode; and
a transformer holder printed circuit board on which the high voltage generator is soldered.
9. The ionizer according to claim 8,
wherein the air inlet, output nozzle and ion detector are comprised in a main body; and
the inserter assembly is detachably insertable into the main body.