United States Patent	12390549
Kind Code	B2
Date of Patent	August 19, 2025
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Airborne virus protection and disinfection device and method of manufacturing

Abstract

An airborne virus protection and disinfection (AIRVPD) device includes positive and negative electrodes arranged to form an electrode fluid path therebetween and a high-voltage converter configured to deliver power to the positive and negative electrodes to trigger a redox reaction. The AIRVPD device also includes a chemical disinfecting unit having a sponge material associated with at least one of the positive and negative electrodes and capable of becoming impregnated with an antimicrobial capable of killing airborne viruses. The AIRVPD device further includes a housing encasing the positive and negative electrodes, the high-voltage converter, and the chemical disinfecting unit. The housing includes an inlet and an outlet in fluid communication with each other via the electrode fluid path. Ionized air with charged droplets external to the AIRVPD device is able to flow through the AIRVPD device for disinfection and neutralization.

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Appl. No.: **17/304753**

Filed: **June 25, 2021**

Prior Publication Data

Document Identifier	Publication Date
US 20220257822 A1	Aug. 18, 2022

Related U.S. Application Data

us-provisional-application US 63200149 20210217

Publication Classification

Int. Cl.: **A61L9/22** (20060101); **A61L9/14** (20060101); **A61L9/20** (20060101)

U.S. Cl.:

CPC **A61L9/22** (20130101); **A61L9/14** (20130101); **A61L9/20** (20130101); A61L2209/213 (20130101)

Field of Classification Search

CPC: A61L (9/22); A61L (9/14); A61L (9/20); A61L (2209/213); A61L (9/18); A61L (2209/15); A61L (2202/25); A61L (2209/14); A61L (2/10); A61L (2202/122); A61L (2101/26); A61L (2209/134); A61L (2202/11); A61L (2202/26); A61L (2209/12); B03C (3/383); B03C (3/60); B03C (3/32); B03C (3/368); B03C (3/016); B03C (2201/10); A61M (16/1065); A61M (16/06); A62B (23/025); A62B (23/02); A62B (7/10)

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION (1) The present invention claims the benefit of U.S. Provisional Patent Application Ser. No. 63/200,149, filed Feb. 17, 2021, the disclosure of which is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION
(1) Embodiments of the present invention relate to a device for protecting against airborne viruses, and, more particularly, to a device that collects and disinfects droplets of infected bodily fluid in air to prevent the spread of airborne viruses.
(2) Airborne viruses are those that are capable of becoming suspended in air. Many airborne viruses plague humans, animals, or both throughout the world. Some examples of airborne viruses are rhinoviruses that cause common cold symptoms, influenza viruses, varicella viruses, the measles

virus, the mumps virus, the hanta virus, viral meningitis, severe acute respiratory syndrome (SARS), and coronaviruses such as, for example, coronavirus disease 2019 (COVID-19). Airborne viruses tend to spread easily and quickly and, as such, are often harder to control than pathogens that spread in other ways.

(3) Those who have not yet established an immunity to an airborne virus, either by way of already being infected or by vaccination, and those who have underlying illnesses or weakened immune systems that make them more likely to get an infection are susceptible to airborne viruses. Individuals infected with airborne viruses will typically spread them when they cough or sneeze, but can also spread them by merely breathing or talking. Regardless of how airborne viruses are expelled from a host, airborne viruses can infect individuals in different ways. Some airborne viruses can live on surfaces for a period of time and be transmitted when people touch the surface and then their eyes, noses, or mouths. Further, airborne viruses are so small that they essentially become an aerosol that may infect a number of individuals who breathe in the infectious aerosol.

(4) Most airborne viruses are fairly unstable after leaving the bodies of their hosts, but droplets of infected bodily fluids, and especially micro droplets, exhaled by infectious people can remain suspended for hours and travel far distances on air currents. Thus, although transmission by way of these respiratory droplets is most likely to occur in close proximity to infectious people—generally within six feet—people can still be exposed to the droplets at greater distances from infectious people and many hours after they have left the area, as long as the droplets are allowed to remain in the air and/or on surfaces. People utilize many types of equipment and materials in attempting to prevent the spread of airborne viruses by droplets. For example, people will often wear and/or use face masks and shields, glasses, gloves, disinfecting wipes, hand sanitizer, and antibacterial hand soap. However, none of these can guarantee total protection from and/or disinfection of airborne viruses, even when they are used together.

(5) It would therefore be desirable to provide a device that can protect against airborne viruses while also disinfecting airborne viruses.

BRIEF STATEMENT OF THE INVENTION

(6) Embodiments of the present invention are directed to an airborne virus protection and disinfection (AIRVPD) device that prevents contact with airborne viruses and disinfects airborne viruses simultaneously.

(7) In accordance with one aspect of the invention, an AIRVPD device includes a positive electrode and a negative electrode in close proximity to, but spaced away from, the positive electrode to form an electrode fluid path between the positive and negative electrodes. The AIRVPD device additionally includes a high-voltage converter configured to deliver power to the positive and negative electrodes in order to trigger a redox reaction at each of the positive and negative electrodes such that the positive electrode attracts negatively charged particles and the negative electrode attracts positively charged particles. Furthermore, the AIRVPD device includes a chemical disinfecting unit having a sponge material associated with and extending along a length of at least one of the positive and negative electrodes. The sponge material is capable of becoming impregnated with an antimicrobial capable of killing airborne viruses. Moreover, the AIRVPD device includes a housing encasing the positive and negative electrodes, the high-voltage converter, and the chemical disinfecting unit and including an inlet and an outlet in fluid communication with each other via the electrode fluid path. The housing is configured such that ionized air with charged droplets external to the AIRVPD device is able to flow into the AIRVPD device through the inlet of the housing, through the electrode fluid path for disinfection by the antimicrobial and for neutralization by the positive and negative electrodes, and through the outlet of the housing and out of the AIRVPD device.

(8) In accordance with another aspect of the invention, a kit for protection against and disinfection of airborne viruses includes an ionizer configured to produce ions for electrically charging air having droplets and at least one AIRVPD device. The at least one AIRVPD device includes a

converter configured to convert a power from a power supply to a high-voltage, low-current power across a positive side and a negative side thereof and a pair of electrodes having a cathode coupled to the negative side of the converter and an anode coupled to the positive side of the converter and positioned adjacent to, but electrically isolated from, the cathode. The cathode and anode are configured to receive the high-voltage, low-current power from the converter to induce a redox reaction at the cathode and anode and are arranged to form an electrode fluid path therebetween. The at least one AIRVPD device also includes a chemical disinfecting unit with a sponge material arranged on at least one of the cathode and anode and capable of impregnation with an antimicrobial capable of killing airborne viruses. The sponge material is configured to supply the antimicrobial to the at least one of the cathode and anode. In addition, the at least one AIRVPD device includes a case positioned around the converter, the pair of electrodes, and the chemical disinfecting unit. The case includes an inlet and an outlet in fluid communication with each other through the electrode fluid path. Ionized air having charged droplets is able to flow into the AIRVPD device through the inlet of the case, along the electrode fluid path for charge neutralization and disinfection, and through the outlet of the case to exit the AIRVPD device.
(9) In accordance with yet another aspect of the invention, a method of manufacturing an AIRVPD device includes arranging a pair of electrodes comprising a positive electrode and a negative electrode in close proximity to, but electrically isolated from, one another to form an electrode fluid path therebetween. The method further includes coupling a high-voltage converter to the positive and negative electrodes for introducing a redox reaction at the positive and negative electrodes and positioning a chemical disinfecting unit including a sponge material capable of becoming impregnated with an antimicrobial adjacent to at least one of the positive and negative electrodes to deliver the antimicrobial to the at least one of the positive and negative electrodes adjacent thereto. The method additionally includes encasing the positive and negative electrodes, the high-voltage converter, and the chemical disinfecting unit in a housing comprising an inlet and an outlet in fluid communication with each other and the electrode fluid path.
(10) Various other features and advantages of the present invention will be made apparent from the following detailed description and the drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) The drawings illustrate embodiments presently contemplated for carrying out the invention.
(2) In the drawings:
(3) FIG. **1** is a block diagram of an AIRVPD system including an AIRVPD device, according to an embodiment of the invention.
(4) FIGS. **2** and **3** are perspective top and bottom views, respectively, of a personal and portable AIRVPD device wearable on a user's head, according to an embodiment of the invention.
(5) FIGS. **4** and **5** are perspective top and bottom views, respectively, of a personal and portable AIRVPD device wearable around a user's neck, according to an embodiment of the invention.
(6) FIG. **6** is a top perspective view of an AIRVPD device for use on a surface or with an apparatus, according to an embodiment of the invention.
(7) FIG. **7** is a perspective view of a modular arrangement of a plurality of the AIRVPD device shown in FIG. **4** for protecting a user sitting in or standing at an apparatus, according to an embodiment of the invention.
(8) FIGS. **8** and **9** are bottom and top perspective views, respectively, of an integrated AIRVPD device for protecting a user sitting in or standing at an apparatus, according to an embodiment of the invention.
(9) FIGS. **10** and **11** are perspective top views of an AIRVPD device for protecting an entire room,

according to an embodiment of the invention.

(10) FIG. **12** is a perspective view of a plurality of the module AIRVPD device shown in FIGS. **10-11** arranged for protecting a large area, according to an embodiment of the invention.

DETAILED DESCRIPTION

(11) Embodiments of the present invention provide for an AIRVPD device and a method for making the same. The AIRVPD device has positive and negative electrodes in close proximity to, but spaced away from, each other such that they are electrically isolated from each other. The AIRVPD device also includes a converter configured to deliver a high-voltage, low-current power to the positive and negative electrodes in order to trigger a redox reaction at each of the positive and negative electrodes so that the positive and negative electrodes attract negative and positive particles, respectively. At least one of the positive and negative electrodes is associated with a chemical disinfecting unit that supplies an antimicrobial capable of killing airborne viruses to the positive electrode and/or negative electrode. A housing having an inlet and an outlet encases the positive and negative electrodes, converter, and chemical disinfecting unit. A flow path through the inlet, between the positive and negative electrodes, and through the outlet allows ionized air having charged droplets of bodily fluid to flow through the AIRVPD device for charge neutralization and disinfection of airborne viruses.

(12) Referring to FIG. **1**, a block diagram of a system **10** for protection against and disinfection of airborne viruses having an ionizer **12** and an AIRVPD device **14** is shown, according to an embodiment of the invention. Ionizer **12** uses a high voltage to provide either a positive or negative electrical charge to air particles that move through ionizer **12**. As a result ionizer **12** produces a plurality of air ions that are introduced into the environment. These air ions are intercepted by droplets of bodily fluid shed from individuals due to breathing, talking, coughing, sneezing, and any other actions that result in droplets of bodily fluid being expelled into the environment. These droplets may include both non-infected droplets and droplets infected with airborne viruses. In either case, the droplets obtain a strong electrical charge when they intercept the air ions. As a non-limiting example, the charge of the droplets may increase by approximately 10 times after interception of the air ions. The type of charge will depend on the charge of the air ion(s) intercepted by the droplets. Regardless, the operation of ionizer **12** results in ionized air with charged droplets **16** that may be drawn into AIRVPD device **14** for disinfection.

(13) AIRVPD device **14** is positioned in the area of ionizer **12** such as, for example, adjacent ionizer **12** or at least in the same room as ionizer **12**. Alternatively, ionizer **12** may be coupled to inlet **20** or be built into AIRVPD **14**. As will discussed in more detail below with respect to FIGS. **2-12**, AIRVPD device **14** may be constructed as a device for either personal use, use with an apparatus, use in an entire room, or use in a larger area. AIRVPD device **14** includes a housing or case **18** having an inlet **20** and an outlet **22** in fluid communication with each other through an interior **23** thereof. Each of inlet **20** and outlet **22** includes at least one respective opening **24**, **26**, but may include a plurality of openings **24**, **26**. Housing **18** may be made from conductive materials (for example, metallic materials such as aluminum), non-conductive or electrically insulating materials (for example, plastic), or a combination of such materials. However, non-conductive materials are preferred to aid in keeping components of AIRVPD device **14** electrically isolated from each other.

(14) A high-efficiency particulate air (HEPA) filter **28** is positioned just inside interior **23** of housing **18** through inlet **20** for filtering ionized air with droplets **16** flowing into AIRVPD device **14**. A fan **30** is positioned behind HEPA filter **28** such that ionized air with charged droplets **16** must flow through HEPA filter **28** before reaching fan **30**. When AIRVPD device **14** is a personal or smaller modular device, fan **30** does not need to be especially powerful and may be a small, quiet device that is not burdensome to a user of AIRVPD device **14** by either its size or noise generated. When AIRVPD device **14** is a larger modular device or configured for a specific apparatus or area, fan **30** may be larger and more powerful. In fact, fan **30** may optionally be

positioned external to housing **18** in some embodiments.

(15) In various embodiments, fan **30** may have an airflow range of approximately 35 cubic feet per minute (approximately 0.016 cubic meters per second) to approximately 3,000 cubic feet per minute (approximately 1.42 cubic meters per second), depending on the size of the room in which AIRVPD device **14** is located and how many AIRVPD devices **14** are being utilized in the room. As a non-limiting example of fan **30**, when fan **30** is used a single room with a volume of approximately 1,400 cubic foot (approximately 40 cubic meter), fan **30** may have an airflow of at least approximately 35 cubic feet per minute (approximately 0.016 cubic meters per second). Regardless of the configuration of fan **30**, fan **30** is designed to create a jet or blade of fluid around housing **18** in order to attract ionized air with droplets **16** into housing **18**. This jet or blade of fluid collects the ionized air with charged droplets **16** before any infected droplets of bodily fluid can reach an individual.

(16) AIRVPD device **14** also includes a pair of electrodes **32** including a positive electrode or anode **34** and a negative electrode or cathode **36** within interior **23** of housing **18**. Cathode **34** and anode **36** are made from a conductive material such as, for example, aluminum, copper, silver-plated copper, sponge copper, or silver-plated sponge copper. In a non-limiting example, anode **34** is made of copper, and cathode **36** is made of silver-plated sponge copper. In general, a length of anode **34** and cathode **36** extends through as much of interior **23** of housing **18** as possible. Anode **34** and cathode **36** are positioned in close proximity with one another. However, anode **34** and cathode **36** are spaced away from each other such that they are electrically isolated from each other by air. Additionally, even when housing **18** is formed of non-conductive materials, anode **34** and cathode **36** are typically electrically isolated from housing **18** by a high-voltage isolation or insulation material (not shown for simplicity), such as, for example, polytetrafluoroethylene (PTFE), ceramic, porcelain, silicone, or epoxy, to avoid creating a path directly between anode **34** and cathode **36** due to issues such as, for example, the aging of materials, moisture absorption, and impurities. As a non-limiting example of the distance between anode **34** and cathode **36**, anode **34** and cathode **36** may be spaced apart at any point by a distance in a range between approximately 0.1 inches (0.254 centimeters) and approximately 0.2 inches (0.508 centimeters). Since anode **34** and cathode **36** are spaced apart from each other, an electrode fluid path **35** is present between anode **34** and cathode **36** where air can flow from inlet **20** of housing **18** to outlet **22** of housing **18**.

(17) Anode **34** and cathode **36** may be constructed in a variety of shapes. As non-limiting examples, anode **34** and cathode **36** may be constructed as straight cylindrical or square sections. However, since straight cylindrical and square section designs will not maximize the area of anode **34** and cathode **36** exposed to air, other designs may result in a greater efficiency. As a non-limiting example, anode **34** and cathode **36** may be constructed in a hair comb style arrangement such as that shown in FIG. **1**. That is, each of anode **34** and cathode **36** includes a respective base **37** and a plurality of fins **39** extending substantially perpendicular to base **37**. Adjacent fins **39** are spaced apart from each other by cavities **41**. By arranging anode **34** and cathode **36** in an alternating manner such that fins **39** of anode **34** extend into cavities **41** of cathode **36** and fins **39** of cathode **36** extend into cavities **41** of anode **34**, the design resembles a hair comb and results in an arrangement that will expose anode **34** and cathode **36** to more air than a straight cylindrical or square design. Thus, the hair comb style arrangement will operate more efficiently than a straight cylindrical or square design.

(18) Further, at least one of anode **34** and cathode **36** is associated with a chemical disinfection unit **46**. Chemical disinfection unit **46** is positioned adjacent to, coupled to, or integrated or built into anode **34** and/or cathode **36** and generally included in the form of a porous or sponge material **47**, but may alternately or additionally include one or more reservoirs or storage tanks **49**. As non-limiting examples, sponge material **47** may be made from sponge copper or silver-plated sponge copper and may be shaped as a strip or other convenient shape, depending on the shape of housing **18**. Sponge material **47** is typically located along at least most of the length of and adjacent base **37**

of its associated anode **34** and/or cathode **36** opposite fins **39**. Reservoirs **49** are typically located adjacent sponge material **47** or adjacent base **37** of its associated anode **34** and/or cathode **36** opposite fins **39**.

(19) Sponge material **47** and reservoirs **49** will be impregnated with or contain an antimicrobial, such as, for example, an antiseptic, disinfectant, or germicide, that will kill airborne viruses on contact. The antimicrobial may include a high concentration of alcohol such as, for example, at least 50% alcohol. The purpose of chemical disinfecting unit **46** is to dispense the antimicrobial onto anode **34** and/or cathode **36**. One or both of anode **34** and cathode **36** can also be plated with one or more materials that can aid in the disinfection process such as, for example, silver. AIRVPD device **14** may optionally include a plurality of ultraviolet (UV) light-emitting diodes (LEDs) **43** as an additional aid to the disinfection process. UV LEDs **43** may be integrated in a UV LED bar **43** and may receive power from power source **44**. UV light is efficient in disinfection of airborne viruses, and UV LEDs **43** do not require a large amount of power.

(20) Anode **34** and cathode **36** are coupled to a converter **38** by way of respective positive and negative rails **40**, **42** associated with converter **38**. Converter **38** receives power from a power source **44** and outputs a direct current (DC) power to anode and cathode **34**, **36** that has a high voltage and a low current. Power source **44** may also power fan **30** and UV LEDs **43**. The level of current that converter **38** outputs to anode **34** and cathode **36** is usually less than 1 mA, and the level of voltage converter **38** provides to anode **34** and cathode **36** is generally between approximately 2,500 V and approximately 5,000 V, depending on the distance between the anode and cathode. As a non-limiting example, when anode **34** and cathode **36** are spaced apart by approximately 0.1 inches (0.254 centimeters), converter **38** may supply approximately 2,500 V to anode **34** and cathode **36**. As another non-limiting example, when the distance between anode **34** and cathode **36** is approximately 0.2 inches (0.508 centimeters), converter **38** may provide approximately 4,500 V to anode **34** and cathode **36**.

(21) Although converter **38** and power source **44** are shown external to housing **18** in FIG. **1**, converter **38** and/or power source **44** may or may not be positioned within housing **18**. As a non-limiting example, power source **44** may be a battery within a battery compartment (not shown in FIG. **1**) that outputs a DC power, and converter **38** may be a DC-to-DC converter such as, for example, a high-frequency DC-to-DC step-up converter that operates at a high efficiency and does not emit an audible noise to a user of AIRVPD device **14**. In that case, both DC-to-DC converter **38** and battery **44** may be positioned in interior **23** of housing **18**. As another non-limiting example, power source **44** may be an alternating current (AC) power source or DC power source external to AIRVPD device **14**, such as, for example, a DC battery, a generator, or the utility power from an electrical socket. When power source **44** is an AC power source, converter **38** may be an AC-to-DC converter positioned either external to or in interior **23** of housing **18**.

(22) Since converter **38** provides a high voltage to anode **34** and cathode **36**, AIRVPD device **14** is typically equipped with safety electronics. More specifically, in some embodiments, AIRVPD device **14** will include optional humidity sensors **48** to detect when a level of humidity is too high or if AIRVPD device **14** is submerged in liquids accidentally, especially in the case that AIRVPD device **14** is a personal and portable apparatus. Humidity sensors **48** are positioned in various locations in AIRVPD device **14** so that liquids can be immediately detected in the event AIRVPD device **14** is submerged. Additionally, AIRVPD device **14** may include a spark detector **50**. Sparks could appear between anode **34** and cathode **36** due to various environmental conditions. If humidity sensors **48** sense that the humidity in AIRVPD device **14** has reached or crossed a preset humidity threshold or spark detector **50** detects a spark between anode **34** and cathode **36**, converter **38** will stop providing power to anode **34** and cathode **36** and an alarm will be triggered.

(23) According to the configuration of AIRVPD device **14** described above, AIRVPD device **14** is able to protect against and disinfect droplets bodily fluid that are infected with airborne viruses. Initially, ionized air with charged droplets **16** is drawn into AIRVPD device **14** through opening **24**

of inlet **20** of housing **18** by fan **30** before coming into contact with an individual or individuals in the area. Ionized air with charged droplets **16** passes through HEPA filter **28** and fan **30** before reaching anode **34** and cathode **36**. At this point, converter **38** is delivering the high-voltage, low-current DC power to anode **34** and cathode **36** to trigger or induce a redox reaction at anode **34** and cathode **36**. That is, the application of the high-voltage, low-current DC power to anode **34** and cathode **36** results in oxidation occurring at anode **34** and reduction occurring at cathode **36**. The redox reaction thus causes a decrease in electrons at anode **34** and an increase of electrons at cathode **36**. As such, anode **34** is positively charged to attract negatively charged particles and cathode is negatively charged to attract positively charged particles. Thus, positively charged air ions and droplets in ionized air with charged droplets **16** will be attracted to cathode **36**, and negatively charged air ions and droplets in ionized air with charged droplets **16** will be attracted to anode **34**.

(24) Once ionized air with charged droplets **16** reaches anode **34** and cathode **36**, it flows through electrode fluid path **35**, where the charged droplets of bodily fluid are deposited on anode **34** and/or cathode **36**. The associated air ions and charged droplets of bodily fluid are neutralized by anode **34** and cathode **36** and disinfected by the antimicrobial of chemical disinfecting unit **46**. The antimicrobial disinfects any infected droplets of bodily fluid almost instantly upon contact. As ionized air with charged droplets **16** is being neutralized and initially disinfected, UV LEDs or UV LED bar **43** provides additional disinfection. After the neutralization and disinfection process is complete, the neutralized and disinfected droplets of bodily fluid evaporate from anode **34** and/or cathode **36** and pass through opening **26** of outlet **22** of housing **18** with the neutralized air particles as clean air **51**. By collecting the droplets of bodily fluid on anode **34** and/or cathode **36** and allowing them to evaporate, AIRVPD device **14** will kill the germs in the droplets without affecting the humidity of the air around AIRVPD device **14**.

(25) Referring now to FIGS. **2-12**, a plurality of configurations of AIRVPD device **14** are shown, according to embodiments of the invention. The AIRVPD devices shown in FIGS. **2-12** are arranged similarly to AIRVPD device **14** and, thus, like element therein are numbered identical to corresponding elements in AIRVPD device **14**. Further, in the AIRVPD devices shown in FIGS. **2-12**, chemical disinfecting unit **46** is only associated with cathode **36**. However, as described above, chemical disinfecting unit **46** may be associated with anode **34** as an alternative or in addition to cathode **36**, depending on the charge ionizer **12** is configured to produce in ionized air with charged droplets **16**, which is not shown in FIGS. **2-12** for the purpose of clarity. Further, the positioning of the various components in the AIRVPD devices of FIGS. **2-12** are non-limiting and can be varied based on preference and/or in order to optimize utility of the components. For example, UV LED bar **43** may be positioned at various locations within housing **18** including on the opposite side of anode **34** and cathode **36** from that shown.

(26) Referring initially to FIGS. **2** and **3**, perspective top and bottom views of an AIRVPD device **52** are shown, according to an embodiment of the invention. AIRVPD device **52** is designed as a personal and portable device wearable on a user's head. That is, AIRVPD device **52** includes an adjustable bracket **54** such that an individual can wear AIRVPD device **52** like a hat or visor. Adjustable bracket **54** includes a head rest **56**, such as, for example, a sponge or other comfortable and/or absorbent material, for a user's forehead in order to make wearing AIRVPD device **52** more comfortable and/or to absorb perspiration. AIRVPD device **52** further includes a face shield **58** for additional user protection from infected droplets of bodily fluid.

(27) Since AIRVPD **52** is configured for personal use, power source **44** in AIRVPD device includes one or more DC batteries located in a battery compartment **60**, and converter **38** is a DC-to-DC converter. As a non-limiting example of power source **44**, power source **44** could include two 9-V batteries in a battery compartment **60** that can be replaced by a user of AIRVPD device **52**, as necessary. DC batteries **44** provide power to DC-to-DC converter **38** and to two fans **30** with corresponding HEPA filters **28**. Fans **30** draw ionized air with charged droplets into two openings

24 of inlet **20** in a top surface **62** of housing **18** and through HEPA filters **28** to anode **34** and cathode **36**. Generally, anode **34** and cathode **36** are spaced apart by approximately 0.1 inches (0.254 centimeters) in this embodiment so that converter **38** can supply a voltage at the low end of the voltage range—approximately 2,500 V. After passing through electrode fluid path **35** between anode **34** and cathode **36** and chemical disinfection unit **46** in the form of a strip of sponge material **47**, the ionized air with charged droplets **16** has been neutralized and disinfected. Additional disinfection is provided by UV LED bar **43** before the now clean air passes through opening **26** of outlet **22**, which is a slit in a bottom surface **64** of housing **18**.

(28) Referring now to FIGS. **4-5**, perspective top and bottom views of an AIRVPD device **66** are shown, according an embodiment of the invention. AIRVPD device **66** is designed as a personal and portable device wearable around a user's neck. That is, housing **18** is arranged as a collar in s U-shape to fit around a user's neck on top of the shoulders. Similarly to AIRVPD device **52** shown in FIGS. **2-3**, since AIRVPD device **52** is a personal device, power source **44** includes one or more DC batteries, such as, for example, two 9-V batteries, in battery compartment **60**, and converter **38** is a DC-to-DC converter. DC batteries **44** provide power to DC-to-DC converter **38** and to two fans **30** with corresponding HEPA filters **28**.

(29) Fans **30** draw ionized air with charged droplets into two openings **24** of inlet **20** in a bottom surface **68** of housing **18** and through HEPA filters **28**. After passing through HEPA filters **28**, the ionized air with charged droplets **16** travels to anode **34** and cathode **36**, which are preferably, but not necessarily spaced apart by approximately 0.1 inches (0.254 centimeters). When the distance between anode **34** and cathode **36** is approximately 0.1 inches (0.254 centimeters), DC-to-DC converter **38** may apply a voltage of approximately 2,500 V to the anode **34** and cathode **36**. When the ionized air with charged droplets passes through electrode fluid path **35** between anode **34** and cathode **36** and chemical disinfection unit **46** in the form of a strip of sponge material **47** and optional reservoirs **49**, the ionized air with charged droplets **16** has been neutralized and once-disinfected. UV LED bar **43** is arranged in housing **18** after chemical disinfection unit **36** in order to provide a second round of disinfection. After being neutralized and twice-disinfected, the now clean air flows through opening **26** of outlet **22**, which is arranged as a slit in a top surface **70** of housing **18**.

(30) Referring now to FIG. **6**, a top perspective view of an AIRVPD device **72** is shown, according to an embodiment of the invention. One or more AIRVPD devices **72** can be configured for a variety of different applications. Housing **18** of AIRVPD device **72** is substantially rectangular or bar-shaped. As AIRVPD device **72** is shown in FIG. **6**, power source **44** may be in the form of DC batteries in battery compartment **60** or in the form of an external DC or AC power source **44**, such as, for example, a larger DC battery, an AC generator, or utility power, coupled to AIRVPD device **72** via wiring **74**, which may be direct wiring or a power cable such as, for example, an AC power cable for an electrical socket. In the case that AC power is delivered via wiring **74**, converter **38** may be in the form of an AC-to-DC converter.

(31) Power source **44** delivers power to converter **38** and two fans **30**, each having a corresponding HEPA filter **28**. In operation, fans **30** draw ionized air with charged droplets through a plurality of openings **24** in inlet **20** located at each of two ends **73**, **75** of housing **18** and HEPA filter **28** to the electrode path **35** between anode **34** and cathode **36**, which are spaced apart by approximately 0.1 inches (0.254 centimeters). Converter **38** thus supplies approximately 3,500 V to anode **34** and cathode **36**. The ionized air with charged droplets passing through electrode fluid path **35** is neutralized and disinfected with the antimicrobial impregnated in sponge material **47** of chemical disinfecting unit **46**. Thereafter, the neutralized and once-disinfected air with droplets passes by UV LED bar **43** for supplemental disinfection before exiting housing **18** through a plurality of openings **26** in outlet **22** located on a side **77** of housing **18** as clean air.

(32) As noted above, AIRVPD device **72** may be configured for use on a surface such as, for example, a desktop, countertop, or even the floor. This surface configuration is meant for personal

use in an area around a user in an office or similar or type of room. As a non-limiting example of use for AIRVPD **72** in this context, a single AIRVPD device **72** may be used for one person in a room with an approximately 1,400 cubic foot (approximately 40 cubic meter) volume. The design allows users to easily carry surface AIRVPD device **72** from room to room without having to wear surface AIRVPD device **72**. However, surface AIRVPD device **72** works best when left in the same area for an extended period of time such as, for example, 30 minutes. Surface AIRVPD device **72** typically includes power source **44** in the form of DC batteries in battery compartment **60**, but may alternatively couple to an external power source **44** via wiring **74**.

(33) Referring now to FIG. **7**, a perspective view of a modular arrangement **76** of a plurality of AIRVPD devices **72** for protecting a user sitting in or standing at an apparatus is shown, according an embodiment of the invention. Arrangement **76** may be used with a variety of different apparatus, such as, for example, a chair, a desk, a kiosk, or another similar apparatus in which a user may sit or at which a use may stand. In the embodiment shown in FIG. **7**, four AIRVPD devices **72** are illustrated. However, a different number of AIRVPD devices **72** may also be used. In order to provide protection for a user sitting in or standing at the apparatus, arrangement **76** of AIRVPD devices **72** is positioned at some point above the apparatus by either mounting them to the apparatus or to the ceiling above the apparatus.

(34) In this embodiment, each AIRVPD device **72** is designed in the same manner as for use on a surface, with the exception that, in arrangement **76**, AIRVPD device **72** typically includes wiring **74** to an external AC or DC power source **44** rather than an internal DC power source **44**. As such, converter **38** may be an AC-to-DC converter. In various embodiments, external power source **44** is an independent power source included in the apparatus. As a non-limiting example, the apparatus may include a DC battery, in which case converter **38** would be a DC-to-DC converter. In any case, arrangement **76** of AIRVPD devices **72** results in a jet of air forming around the apparatus and drawing in all ionized air with charged droplets such that an infected droplet of bodily fluid has essentially no chance to reach a user sitting in or standing at the apparatus.

(35) Referring now to FIGS. **8** and **9**, bottom and top perspective views, respectively, of an integrated AIRVPD device **78** for use with an apparatus is shown, according to an embodiment of the invention. Integrated AIRVPD device **78** is a modified version of arrangement **76** of AIRVPD devices **72** of FIG. **7**, with the components of each AIRVPD device **72** being integrated into a single housing **18**. More specifically, integrated AIRVPD **78** includes a plurality of anodes **34**, cathodes **36**, converters **38**, UV LED bars **43**, and chemical disinfecting units **46** that form a plurality of AIRVPD devices **72** in integrated housing **18**. Thus, integrated AIRVPD device **78** may be used in a similar manner as arrangement **76** of AIRVPD devices **72**. As such, integrated AIRVPD device **78** is essentially a merging of the four AIRVPD devices **72** illustrated in FIG. **7** into a single housing **18**. Thus, similarly to arrangement **76** of AIRVPD devices **72**, integrated AIRVPD device **78** is positioned above an apparatus by mounting it to the apparatus or to the ceiling above the apparatus and includes wiring **74** coupled to an external power source **44** such as a generator, an electrical socket, or a DC battery within the apparatus, as non-limiting examples.

(36) However, in integrated AIRVPD device **78**, each anode **34** and cathode **36** pair is spaced apart by approximately 0.2 inches (0.508 centimeters), and converter **38** supplies approximately 4,500 V to anode **34** and cathode **36**. Further, integrated AIRVPD device **78** does not include any internal fans. Instead, an external supply of ionized air is supplied by ionizer **12** (shown in FIG. **1**), which is coupled to inlet **20** at inlet ports **80**. Alternatively, ionizer **12** may supply ionized air as a built-in ionizer. Further, outlet **22** of integrated AIRVPD device **78** includes a plurality of openings **26** on a bottom surface **82** of housing **18**. Like arrangement **76** of AIRVPD devices **72**, operation of integrated AIRVPD **78** results in results in a jet of air forming around the apparatus associated therewith. The jet of air draws in charged droplets of bodily fluid such that an infected droplet of bodily fluid has essentially no chance of reaching the apparatus.

(37) Referring now to FIGS. **10** and **11**, perspective top views of an AIRVPD device **83** for

protecting an entire room is shown, according to an embodiment of the invention. AIRVPD device **83** shares many characteristics of AIRVPD device **72** shown in FIG. **6**. However, AIRVPD device **83** differs from AIRVPD device **72** shown in FIG. **6** in that it includes one fan **30** and HEPA filter **28** at end **75** of housing **18** and one set of openings **26** of outlet **22** on side **77** of housing **18**. Further, AIRVPD device **83** is coupled to an external power source **44** via wiring **74**, and external power source **44** supplies 4,500 V to anode **34** and cathode **36**, which are spaced apart by approximately 0.2 inches (0.508 centimeters). Depending on the location of AIRVPD device **83**, it may be beneficial to wire AIRVPD device **83** directly into an electrical circuit with wiring **74** rather than including wiring **74** as a power cable for plugging into an electrical socket. While the principle of operation of AIRVPD device **83** is essentially the same as that of AIRVPD **72** shown in FIG. **6**, the different configuration of AIRVPD device **83** allows AIRVPD device **83** to protect an entire room (not shown in FIG. **10** or **11**).

(38) Typically, AIRVPD device **83** will be mounted on the ceiling or high on the wall in a room. Hence, AIRVPD device **83** will be positioned farther away from a user and can incorporate a larger, more powerful fan **30** therein. This larger, more power fan **30** enables AIRVPD device **83** to protect a greater area that AIRVPD device **72** of FIG. **6** such as an entire room. While such a fan **30** may be noisier, it will have minimal or no effect on the user due to the larger distance away from the user. Further, having openings **26** of outlet **22** only on side **77** of housing **18** provides for AIRVPD device **83** to be positioned on the perimeter of a room on a wall or ceiling. In any case, side **77** of housing **18** with openings **26** of outlet **22** will ideally be positioned such that outlet **22** is directed toward the middle or center of a room in order to provide clean air into the environment.

(39) Referring now to FIG. **12**, a perspective view of an arrangement **84** of a plurality of AIRVPD devices **83** for a large area **86** is shown, according to an embodiment of the invention. In FIG. **12**, large area **86** is a room **86** with four walls **88** and a ceiling **90**, but large area **86** is not limited to such a configuration. Although 10 AIRVPD devices **83** are illustrated in FIG. **12**, a different number of AIRVPD devices **83** may be used, depending on the size of large area **86** and the spacing between AIRVPD devices **83**. As a non-limiting example, AIRVPD devices **83** may be spaced apart by approximately 24 inches (60.96 centimeters) or more, but this may vary based on the configuration of room **86**.

(40) In arrangement **84** of FIG. **12**, AIRVPD devices **83** are designed in the same manner as that shown in FIGS. **10** and **11**, except that, inlet **20** includes inlet ports **80**, as similarly described above with respect to FIGS. **8** and **9**. As such, AIRVPD devices **83** do not include fan **30** or HEPA filter **28**, but instead receives an external supply of ionized air through inlet ports **80**. Inlet ports **80** are located on side **79** of housing **18** facing adjacent walls **90** of room **86** and opposite side **77** of housing including openings **26** of outlet **22**. As similarly explained above with respect to FIGS. **10** and **11**, side **77** of housing **18** of each AIRVPD device **83** should be positioned facing the center of room **86**. In this manner, outlet **22** is able to direct clean air into the environment.

(41) Beneficially, embodiments of the invention thus provide an AIRVPD device having a pair of electrodes including an anode and a cathode receiving a high-voltage, low-current power from a converter coupled to a power supply. The AIRVPD device further includes a chemical disinfecting unit associated with at least one of the anode and cathode and including a supply of an antimicrobial for killing airborne viruses. Optionally, the AIRVPD device includes a plurality of UV LEDs or UV LED bar for additional disinfecting. The pair of electrodes, converter, chemical disinfecting unit, and UV LED bar are encased by a housing having an inlet and an outlet. A fan or other air supply positioned either in the interior of housing or externally connected to the inlet of the housing will direct ionized air with charged droplets ionized/charged by an ionizer associated with the AIRVPD device into the housing. The ionized air with charged droplets will pass through an electrode fluid path between the anode and cathode, where the charge of the ionized air with charged droplets is neutralized and any infected droplets of bodily fluid is disinfected by the antimicrobial of the chemical disinfecting unit. Thereafter, the neutralized and once-disinfected air

with droplets is additionally disinfected by the UV LED bar before passing through the outlet of the housing as clean air. The many different configurations of the AIRVPD device enable it to be portable or stationary and enable it to protect individuals from contracting airborne viruses on a personal level, in a room, or in larger areas. The AIRVPD device prevents contact with airborne viruses and provides disinfection of airborne viruses simultaneously and with a high efficiency.

(42) Therefore, according to one embodiment of the invention, an AIRVPD device includes a positive electrode and a negative electrode in close proximity to, but spaced away from, the positive electrode to form an electrode fluid path between the positive and negative electrodes. The AIRVPD device additionally includes a high-voltage converter configured to deliver power to the positive and negative electrodes in order to trigger a redox reaction at each of the positive and negative electrodes such that the positive electrode attracts negatively charged particles and the negative electrode attracts positively charged particles. Furthermore, the AIRVPD device includes a chemical disinfecting unit having a sponge material associated with and extending along a length of at least one of the positive and negative electrodes. The sponge material is capable of becoming impregnated with an antimicrobial capable of killing airborne viruses. Moreover, the AIRVPD device includes a housing encasing the positive and negative electrodes, the high-voltage converter, and the chemical disinfecting unit and including an inlet and an outlet in fluid communication with each other via the electrode fluid path. The housing is configured such that ionized air with charged droplets external to the AIRVPD device is able to flow into the AIRVPD device through the inlet of the housing, through the electrode fluid path for disinfection by the antimicrobial and for neutralization by the positive and negative electrodes, and through the outlet of the housing and out of the AIRVPD device.

(43) According to another embodiment of the present invention, a kit for protection against and disinfection of airborne viruses includes an ionizer configured to produce ions for electrically charging air having droplets and at least one AIRVPD device. The at least one AIRVPD device includes a converter configured to convert a power from a power supply to a high-voltage, low-current power across a positive side and a negative side thereof and a pair of electrodes having a cathode coupled to the negative side of the converter and an anode coupled to the positive side of the converter and positioned adjacent to, but electrically isolated from, the cathode. The cathode and anode are configured to receive the high-voltage, low-current power from the converter to induce a redox reaction at the cathode and anode and are arranged to form an electrode fluid path therebetween. The at least one AIRVPD device also includes a chemical disinfecting unit with a sponge material arranged on at least one of the cathode and anode and capable of impregnation with an antimicrobial capable of killing airborne viruses. The sponge material is configured to supply the antimicrobial to the at least one of the cathode and anode. In addition, the at least one AIRVPD device includes a case positioned around the converter, the pair of electrodes, and the chemical disinfecting unit. The case includes an inlet and an outlet in fluid communication with each other through the electrode fluid path. Ionized air having charged droplets is able to flow into the AIRVPD device through the inlet of the case, along the electrode fluid path for charge neutralization and disinfection, and through the outlet of the case to exit the AIRVPD device.

(44) According to yet another embodiment of the present invention, a method of manufacturing an AIRVPD device includes arranging a pair of electrodes comprising a positive electrode and a negative electrode in close proximity to, but electrically isolated from, one another to form an electrode fluid path therebetween. The method further includes coupling a high-voltage converter to the positive and negative electrodes for introducing a redox reaction at the positive and negative electrodes and positioning a chemical disinfecting unit including a sponge material capable of becoming impregnated with an antimicrobial adjacent to at least one of the positive and negative electrodes to deliver the antimicrobial to the at least one of the positive and negative electrodes adjacent thereto. The method additionally includes encasing the positive and negative electrodes, the high-voltage converter, and the chemical disinfecting unit in a housing comprising an inlet and

an outlet in fluid communication with each other and the electrode fluid path.
(45) This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.
(46) While the invention has been described in detail in connection with only a limited number of embodiments, it should be readily understood that the invention is not limited to such disclosed embodiments. Rather, the invention can be modified to incorporate any number of variations, alterations, substitutions or equivalent arrangements not heretofore described, but which are commensurate with the spirit and scope of the invention. Additionally, while various embodiments of the invention have been described, it is to be understood that aspects of the invention may include only some of the described embodiments. Accordingly, the invention is not to be seen as limited by the foregoing description, but is only limited by the scope of the appended claims.

Claims

1. An airborne virus protection and disinfection (AIRVPD) device comprising (a) a housing comprising a first opening and a second opening distal from the first opening, wherein the housing forms an enclosed passageway between the first opening and the second opening capable of channeling a flow of air from the first opening to the second opening; (b) a pair of electrodes located within the enclosed passageway, wherein the pair of electrodes comprises a first electrode and a second electrode, wherein the second electrode is spaced apart from, and proximal to, the first electrode, wherein the pair of electrodes forms an electrode fluid path between the pair of electrodes capable of channeling a flow of air between the pair of electrodes received from the first opening toward the second opening; and (c) a sponge-like material located within the enclosed passageway between the first opening and the second opening, wherein the sponge-like material is capable of becoming impregnated with an antimicrobial substance, wherein the sponge-like material is arranged within the enclosed passageway such that at least a portion of the enclosed passageway forms a channel comprising the sponge-like material, wherein the portion of the enclosed passageway is capable of channeling a flow of air from the first opening to the second opening contacting the sponge-like material without passing through the sponge-like material.
2. The AIRVPD device according to claim 1, wherein the sponge-like material is arranged on, or adjacent to, at least one of the first electrode and the second electrode.
3. The AIRVPD device according to claim 2, wherein the sponge-like material extends along the length of at least one of the first electrode and the second electrode.
4. The AIRVPD device according to claim 1, wherein the AIRVPD device further comprises a high-voltage converter electrically coupled to the first electrode and the second electrode, wherein the high-voltage converter is configured to deliver power to the first and second electrodes comprising a voltage such that the first electrode is provided with a positive charge and the second electrode is provided with negative charge.
5. The AIRVPD device according to claim 4, wherein the AIRVPD device further comprises a battery capable of being coupled with the high-voltage converter for supplying power to the high-voltage converter.
6. The AIRVPD device according to claim 4, wherein the AIRVPD device further comprises wiring coupled with the high-voltage converter, wherein the wiring is couplable to an external power supply.

7. The AIRVPD device according to claim 4, wherein the high-voltage converter is configured to supply a voltage in the range from between approximately 2,500 V and approximately 5,000 V.
8. The AIRVPD device according to claim 1, wherein each of the first electrode and the second electrode comprises a base; a plurality of fins extending outward from the base; and a plurality of cavities between adjacent fins of the plurality of fins, wherein the fins of the first electrode extend into the cavities of the second electrode and the fins of the second electrode extend into the cavities of the first electrode.
9. The AIRVPD device according to claim 1, wherein the first and second electrodes are spaced apart by a distance in a range between approximately 0.1 inches (0.254 centimeters) and approximately 0.2 inches (0.508 centimeters).
10. The AIRVPD device according to claim 1, wherein the sponge-like material is sponge copper.
11. The AIRVPD device according to claim 1 further comprising an ultraviolet light emitting diode bar positioned within the housing to disinfect air.
12. The AIRVPD device according to claim 1 further comprising a fan disposed in the housing between the first opening and the second opening, wherein the fan is capable of generating a flow of air from the first opening to the second opening.
13. A kit for protection against and disinfection of airborne viruses comprising an ionizer configured to produce ions for electrically charging air having droplets and at least one airborne virus protection and disinfecting (AIRVPD) device according to claim 1.
14. The kit according to claim 13, wherein the pair of electrodes of the at least one AIRVPD device is arranged in a hair comb-style arrangement.
15. The kit according to claim 13, wherein the at least one AIRVPD device further comprises a fan positioned within the case and configured to direct ionized air having charged droplets into the at least one AIRVPD device through the first opening.
16. The kit according to claim 13, wherein at least one electrode of the pair of electrodes of the AIRPVD device is plated with silver.
17. A method for manufacturing an airborne virus protection and disinfection (AIRPVD) device comprising arranging a pair of electrodes in close proximity to, but electrically isolated from, one another to form an electrode fluid path therebetween; coupling a high-voltage converter to the pair of electrodes for introducing a redox reaction at the electrodes; positioning a chemical disinfecting unit including a sponge-like material capable of becoming impregnated with an antimicrobial adjacent to at least one of the electrodes to deliver the antimicrobial to the at least one of the electrodes adjacent thereto; and encasing the pair of electrodes and the chemical disinfecting unit in a housing comprising a first opening and a second opening in fluid communication with each other and the electrode fluid path, wherein: the housing forms an enclosed passageway between the first opening and the second opening capable of channeling a flow of air from the first opening to the second opening; and the sponge-like material is located within the enclosed passageway between the first opening and the second opening, wherein the sponge-like material is capable of becoming impregnated with an antimicrobial substance, wherein the sponge-like material is arranged within the enclosed passageway such that at least a portion of the enclosed passageway forms a channel comprising the sponge-like material, wherein the portion of the enclosed passageway is capable of channeling a flow of air from the first opening to the second opening contacting the sponge-like material without passing through the sponge-like material.
18. The method according to claim 17, wherein the arranging the pair of electrodes comprises (1) providing first and second electrodes, wherein the first and second electrodes each have a base, a plurality of fins extending from the base and a plurality of cavities between adjacent fins of the plurality of fins and (2) positioning the first and second electrodes in a hair comb style arrangement with fins of the first electrode inserted into cavities of the second electrode and fins of the second electrode being inserted into cavities of the first electrode.
19. The method according to claim 17 further comprising arranging an ultraviolet light-emitting

diode bar within the housing between the pair of electrodes and the second opening.
20. The method according to claim 17 further comprising coupling a battery compartment to the high-voltage converter configured to receive a battery therein as the power source for the AIRVPD device.