PORTABLE DIFFUSER

TECHNICAL FIELD

[0001] The invention relates to a portable diffusing technology for use with liquid active materials, with particular regards to essential oils, fragrance oils, water-based fragrances, and the like. The technology can also be used for applications involving portable aerosolisation e.g., as a portable humidifier, for medicine delivery, as an insect repellant, and so on.

BACKGROUND

[0002] The dispersing of active materials (with particular regards to fluid-based active materials) as aerosols is important for a number of applications, including, but not limited to, air fresheners, medical drug delivery systems, fuel systems, analytical instrumentation, insect repellants, hygiene maintenance systems, and so forth. There are a multitude of active material diffusion devices available in the market, all of which use different means for dispersion. For example, some diffusion devices include a heating element for heating an active material in order to evaporate the material. Other diffusion devices utilise an air stream via a fan or an air pump to evaporate and/or stream evaporated active material from the diffusion device into the environment. Other active material diffusion devices dispense active material utilising an ultrasonic disperser. Many of these devices are passive, in that only ambient air flow is required to disperse the active material therein (either liquid, wax-based, microcapsules, or otherwise). Other devices require an active dispersing engine, and are either battery-powered or receive external power e.g., via a cord extending from the device plugged into an external socket.

[0003] An example of a common type of active material used in dispersion devices is essential oil. Essential oils are used for a range of purposes including air freshening and medicinal applications. Often these oils are usually mixed with water and diffused, or are heated with a candle and evaporated. Many diffusing devices for essential oils are known and are commercially available, including, but not limited to, reed diffusers, water-based aroma humidifiers, wax-based diffusers, and air-pump devices. Many of these types of devices are

used for aromatherapy and air freshening. An example of a common type of aromatherapy or air freshening diffuser uses heat to diffuse the active material. Such heat-based diffusers usually require a heat source such as a candle flame or an electric element to evaporate the essential oil/fragrance, but this degrades the quality of the oil and may also pose both smoke inhalation and fire hazards. Aspirator-based diffusers (e.g., that utilise an air pump) also require external source of power due to the large energy consumed by the pump and/or vibrating motor. Examples of patents for essential oil diffusers include pending Singapore Patent Numbers 2013056932 and 2013086236. Other patents can be found for similar devices including U.S. Patent Numbers 8066420 and 8147116, where essential oils are either directly heated or added to water and then dispersed.

[0004] Piezoelectrically-driven liquid atomization apparatus are described in various examples of prior art, including but not limited to, U.S. Patent Numbers 6293474, 6341732, 6382522, 6450419, 68434130, 7469844, 20070012718, 20140191063, 20140263722, and 20150117056. These patents each describe piezoelectrically-driven fluid atomization apparatus, usually comprising a piezoelectric driving engine comprised of ceramic piezoelectric material joined or connected to an atomisation mechanism (e.g., plate, mesh, perforated metal film, and so forth). Driving the piezoelectric engine via an alternating current electrical voltage causes the atomisation mechanism to atomise and disperse the fluid in a controlled and well-defined manner. In terms of fluid delivery to the piezoelectric engine, the fluid can be delivered using a variety of mechanisms, including but not limited to wicking, pumping, air pumping, capillary tubing, mesh capillary wicking, and so forth. Although it is not necessary to include complex electronic circuits apart from those needed to drive the piezoelectric engine, one is often attached with these inventions to provide both greater user control of these devices as well as the requesite electrical current to the various elements of the respective devices.

[0005] A number of air freshening diffusers are capable of diffusing multiple scents, for example, by using a cartridge containing a variety of encapsulated scent elements (comprised of encapsulated or wax-based essential oils, or derivatives thereof). In one example of this type of air freshener, an airflow generator (e.g., fan, pump, air jet, and so forth) is used to generate airflow across the receiving cartridge, and then flow out of an an opening in the device housing. This type of device can diffuse one scent, and then, depending on the

cartridge design, dispense a second scent when the cartridge position is changed. However, this type of device is usually limited to active materials that are solid, such as fragranced waxes. In terms of liquid active materials, there are other examples of diffusing devices that are capable of dispensing multiple liquid active materials from the same device, usually from different dispersing ports. In one example of this type of device, there are three active material liquid reservoirs, and the active material liquid in each reservoir is transmitted to a piezoelectric engine via a wick and dispersed into the environment by ultrasonic vibration. However, in this example, replacement of the active material reservoir is not straightforward, and it is preferred that the active material is fully consumed before the reservoir is replaced. As such, a need remains for device that allows users to disperse multiple active materials as required, while allowing for greater flexibility and greater choice regarding what material to disperse and how to replace each material without necessarily consuming all the active material in the device's reservoirs prior to replacement.

[0006] Importantly, many of the types of diffuser devices such as the examples given above require a significant amount of energy to operate, and thus need an external power source to function; consequently, apart from a few exceptions (e.g., U.S. Patent Number 6802460), these diffusers do not usually have an on-board power source such as a replaceable or rechargeable battery. Additionally, while some of the aforementioned diffusers can disperse multiple scents (e.g., U.S. Patent Number 7469844), replacement or replenishment of the active material reservoir or reservoirs in many commercially available devices is usually difficult to undertake if it is possible at all, and usually requires disassembly and cleaning of the requisite components. While some commercially available essential oil dispersers allow the user to change the dispersing fluid, these devices often require that all of the fluid previously loaded into the device be consumed prior to refilling the reservoir, which reduces the flexibility of the device for the device operator. Furthermore, a number of commercially available devices are designed so that the user cannot easily disassemble the device and access or replenish the fluid reservoir, thus rendering the device disposable in its entirety and adding to cost and waste.

SUMMARY OF THE INVENTION

[0007] According to one aspect of the present invention, an apparatus for dispersing active

materials comprises a housing that includes the dispersing engine, active material transfer mechanism, replaceable active material reservoir container(s) and associated transfer mechanisms, and programmable driving circuitry. The circuitry includes a programmable microprocessor that can be interfaced with either via a direct mechanism (e.g., button interface, touch screen, movement sensor, USB cable attached to a computer or smartphone, and so forth) or via a wireless mechanism (e.g., from an external controller such as a computer or smartphone connected to the device via Bluetooth, IEEE 802.11 standards, and so forth). The circuitry and microprocessor provide a mode of operation that can be user-controlled, in that the device user can determine how the active material is dispensed via the direct interface and/or the wireless interface.

[0008] According to another aspect of the present invention, the active material can be connected to or disconnected from the dispersing apparatus via a simple step of adding or removing the active material reservoir container. The active material reservoir container is designed so that the active material can be readily transported to the piezoelectric dispersing engine via a multi-staged transfer mechanism. In a preferred embodiment, the active material is transferred via a two-stage mechanism. The mode of attachment of the reservoir to the dispersing apparatus can be via using magents, clips, adhesives, screws, bands, and so forth. In a preferred embodiment, the mode of attachment is via magnets.

[0009] In another aspect of the present invention, the number of diffusing systems, comprising piezoelectric diffusing apparatus, transfer mechanisms, and reservoirs, can be greater than one. In one embodiment, the diffusing apparatus and reservoirs are housed as discrete modules in one housing, thus allowing for more than one dispersing system to be contained in one device. In a further embodiment, each dispersing system can be controlled, either as a single and separate dispersion system or together as multiple dispersion systems operating simultaneously, via a single interface that is either a direct mechanism (e.g., button interface, touch screen, movement sensor, USB cable attached to a computer or smartphone, and so forth) or a wireless mechanism (e.g., from an external controller such as a computer or smartphone connected to the device via Bluetooth, IEEE 802.11, and so forth). In a preferred embodiment, there are three identical dispersing systems, including three diffusing apparatus, three transfer mechanisms, and three reservoirs, in one device and all controllable via a direct mechanism and/or wireless interface.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 is an oblique elevation view of one embodiment of the present invention as assembled;

[0011] FIG. 2 is a cutaway cross-section view of the embodiment shown in FIG. 1, with attached active material reservoir container within;

[0012] FIG. 3 is an upper-elevation exploded view of the top section of the embodiment shown in FIG. 1, showing important features of this section;

[0013] FIG. 4 is a lower-elevation exploded view of the top section of the embodiment shown in FIG. 1, showing important features of this section;

[0014] FIG. 5 is an exploded view of the bottom section of the embodiment shown in FIG. 1, with active material reservoir container not shown;

[0015] FIG. 6 is an oblique elevation view of the active material reservoir container;

[0016] FIG. 7 is an exploded view of the active material reservoir container shown in FIG. 6;

[0017] FIG. 8 is an oblique elevation view of an embodiment of the present invention comprising three diffusing systems, as assembled in one housing;

[0018] FIG. 9 is an upper-elevation exploded view of the top section of the embodiment shown in FIG. 8, showing important features of this section;

[0019] FIG. 10 is a lower-elevation exploded view of the top section of the embodiment shown in FIG. 8, showing important features of this section;

[0020] FIG. 11 is an exploded view of the bottom section of the embodiment shown in FIG. 8, with active material reservoir containers not shown.

DETAILED DESCRIPTION

[0021] With reference to the following detailed description, the invention can be better understood when it is considered in conjunction with the drawings accompanying this application. Furthermore, other aspects and advantages of the device of the present invention are given in the following detailed description.

[0022] With reference to FIGS. **1** to **5**, the present invention relates to using an ultrasonic piezoelectric diffusing engine (**30**) to finely disperse fluid delivered via a multi-staged

delivery mechanism (**41** and **42**), along with the controlling electronics (**220**), power source (**223**), and design features of the device housing and integrated components (FIGS. **3** to **5**). The device of the present invention can be used to dispense an active material over a period of time determined by the operator, for which the operator or user can adjust the frequency of dispersion and mode of operation. Furthermore, any active material reservoir containers (**40**, and FIGS. **6** and **7**) placed into the device can be easily removed and replaced by the user.

[0023] With reference to FIGS **2**, **3** and **4**, the invention refers to the assembly of a piezoelectric diffusing engine (**30**) in contact with or very near to an active material fluid delivery component (**41** e.g., wick, capillary, flow tube, dish, and the like). In a preferred embodiment, the piezoelectric diffusing engine (**30**) comprises a ceramic ring enclosing a perforated metal plate, film, or mesh, so that active material fluid can be captured by the metal plate, film, or mesh, and dispersed in aerosolised form into the environment from one or both sides of the metal plate, film, or mesh.

[0024] The piezoelectric diffusing engine (**30**) is mounted in contact with or near to one component of the active material fluid delivery system (**41** and **42**) in the invention housing (**10**, **20**, and **23**). The piezoelectric diffusing engine can be mounted using fixed brackets, clips, gaskets, toric rings (O-rings), glue, pivots, and so forth. In one embodiment, the mountings of the aforementioned types can have an ASTM D2240 type A hardness, also known as Shore A hardness, of between 10-90, preferably between 30-70, more preferably between 45-55.

[0025] In a preferred embodiment shown in FIGS. **2**, **3**, **4**, and **5**, the piezoelectric diffusing engine is mounted using top and bottom toric rings, also known as O-rings (**31a** and **31b**). In this embodiment, the O-rings and piezoelectric engine are mounted between a top plate (**11**) of the top section (**10**) of the housing, which is also the top-most part of the device, and the bottom plate (**12**) of the top section (**10**) of the housing. The O-rings and piezoelectric engine fit into a top cavity (**111**) and a bottom cavity (**112**) in each of the plates. In a preferred embodiment, the plates are joined together with the middle housing section (**20**) by posts (**110a** and **110b**) that slot into ports (**125a** and **125b**) in the bottom plate (**12**), and are attached to the middle housing section by screws (**113a** and **113b**) that are fitted through posts (**213a** and **213a**) in the middle housing section. With regards to the O-rings of this

embodiment (**31a** and **31b**), the O-rings are comprised of a synthetic rubber material, examples of which include, but are not limited to, silicone, nitrile butadiene rubber (Nitrile), ethylene vinyl acetate copolymers (EVM), a fluoroelastomer comprising copolymers of hexafluoropropylene (HFP), vinylidene fluoride (VF2), polyvinylidene fluoride, terpolymers of tetrafluoroethylene (TFE), hexafluoropropylene (HFP) and VF2, perfluoromethylvinylether (PMVE), pentapolymers of TFE, HFP, ethylene, PMVE, and VF2, some combinations of which are commercially available as Viton A, Viton B, Viton F, and generally known as FKM, or, where the perfluoroelastomeric compounds contain an even higher amount of fluoride than the aforementioned combinations, FFKM. In a preferred embodiment, the O-rings are comprised of combinations of aforementioned compounds along with perfluoro(alkylvinyl) ether (PAVE) and either without additions of base-sensitive copolymers HFP and/or VF2 or with lower added concentrations of HFP and/or VF2, combinations of which are commercially available as Viton Extreme TBR-S, Viton Extreme ETP-600S, and Viton Extreme ETP-900.

[0026] Ideally, the active material fluid delivery component (**41**) should be in contact with or very near to the piezoelectric diffusing engine comprises the last stage of the fluid delivery system. The delivery of fluid to the piezoelectric engine can be via a multiplicity of mechanisms, including, but not limited to, wicking, pumping, capillary action, air pumping, hydraulic action, and so forth. In a preferred embodiment, this last stage material comprises a hydrophilic, oleophilic, or both hydro- and oleophilic porous wick made of either natural fibres (e.g., cotton, silk, wood pulp, and the like) or synthetic fibres (e.g., polyethylene, polypropylene, polycarbonate, and the like). In a preferred embodiment, this stage of the fluid delivery material is a rigid, porous wick made of polyethylene. In a more preferred embodiment, this stage of the fluid delivery material is both hydrophilic and oleophilic, in that both water-based active materials and oil-based active materials can be transmitted through the material. In this more preferred embodiment, the rigid, porous, hydrophilic, and oleophilic wick (**41**) is fitted into a cavity (**120**) of the bottom plate (**12**) of the top section (**10**) of the device.

[0027] Regarding the staged delivery mechanism for the active material, specifically an active material fluid, there are various methods for inserting or removing active material reservoir containers into or out of the invention, and such containers may be easily removed and

replaced by the user. With reference to FIGS. **3**, **4**, **5**, **6**, and **7**, in one embodiment, the active material reservoir container (**40**, and FIGS. **6** and **7**) is a container of specific volume from 1 mL to 10 L, preferably 1 mL to 1 L, more preferably 1 mL to 100 mL, and even more preferably 1 mL to 50 mL. In a preferred embodiment, the active material reservoir container is 30 mL. The base (**43**) of the active material reservoir container (**40**) can be made of any compatible storage material such as plastic, e.g., polypropylene (PP), polyethylene terepthalate (PET), polycarbonate (PC), and so forth; or the storage material can be made of glass, e.g., silica, borosilicate, Pyrex, aluminosilicate, and so forth; or the storage material can be made of metal, e.g., stainless steel, aluminium, and so forth. The connection of the active material reservoir container base (**43**) to the device housing can be via screws, clips, magnets, glue, necked seal, and so forth. In a preferred embodiment, the active material reservoir container base (**43**) has a cap (**44**) that is screwed onto the reservoir container, which can be magnetically docked to the last stage of the fluid delivery system. In this preferred embodiment, a washer (**124**) is encased onto the active material reservoir container cap (**44**), which then docks with a ring-shaped magnet (**123**) that is housed in a cavity (**121**) situated in the bottom plate (**12**) of the top section (**10**) of the device, which also houses the last stage of the fluid delivery system, specifically the rigid, porous, hydrophilic, and oleophilic wick (**41**). Regarding the reservoir container cap (**44**), an airway is provided (**45**) in order to ensure uptake of active material by the device is not hindered by pressure differences between the active material storage container (**40**) and the outside environment, resulting from circumstances such as changes in the volume of active material in the container or changes in altitude. Regarding the washer embedded in the cap (**124**), in a preferred embodiment, this washer (**124**) is comprised of two parts, that is a metal washer (**127**) coated with a substance (**126**) in order to reduce leakage from the active material delivery interface, better seal the active material reservoir container (**40**) to the last stage of the fluid delivery mechanism (**41** and **123**), and prolong the lifetime of interface components. In a more preferred embodiment, the metal washer coating substance (**126**) is a synthetic rubber compound, and can be comprised of material similar to the materials used in the aforementioned O-rings, such as, but not limited to, silicone, nitrile butadiene rubber (Nitrile), ethylene vinyl acetate copolymers (EVM), or a fluoroelastomer product such as those commercially known as Viton A, Viton B, Viton F, and generally known as FKM, or, where the perfluoroelastomeric compounds contain an even higher amount of fluoride than the aforementioned combinations, FFKM, as well as commercially available perfluoroelastomers such as Viton Extreme TBR-S,

Viton Extreme ETP-600S, and Viton Extreme ETP-900.

[0028] The delivery of the active material to the last stage of the fluid delivery mechanism can be a single stage or can involve multiple stages. With reference to FIGS. **2**, **3**, **4**, **6**, and **7**, the delivery of fluid to the last stage (**41**) can be via a multiplicity of mechanisms, including, but not limited to, wicking, pumping, capillary action, air pumping, hydraulic action, and so forth. In one embodiment, this delivery mechanism (**42**) utilises a single hydrophilic, oleophilic, or both hydro- and oleophilic porous wick made of either natural fibres (e.g., cotton, silk, wood pulp, and the like) or synthetic fibres (e.g., polyethylene, polypropylene, polycarbonate, and the like), to deliver fluid to the last stage. In a preferred embodiment, the wick (**42**) used for active material delivery is a soft, porous wick made of polyethylene that is both hydrophilic and oleophilic, in that both water-based active materials and oil-based active materials can be transmitted through the material.

[0029] The active material reservoir container (FIGS. **6** and **7**) may contain one of or a combination of a range of active materials, including, but not limited to, a water-based fragrance, an oil-based fragrance, an essential oil, a mixture of essential oils, an insecticide, an insect repellant/attractant, a disinfectant, an air purification agent, an aromatherapy scent comprising oil-based and/or water-based scents, an odor eliminator, an air freshener, and so forth, or combinations thereof. Any combination of types of liquid active materials can be utilized in the active material reservoir container, and can be used with any of the embodiments disclosed in this application. The active material reservoir container can be replaced when empty or whenever the user requires a new active material.

[0030] With reference to FIGS. **3**, **4**, and **5**, the operation of the piezoelectric diffusing engine can be undertaken via a connection to a printed circuit board (PCB, **220**) and associated electronics, including microprocessor. The PCB can be situated in various places, including adjacent to the piezoelectric diffusing engine, or in a different part of the device housing. In a preferred embodiment, the PCB is mounted vertically along the back face of the middle section (**20**) of the device, and is supported by a placeholder (**127**) in the bottom plate (**12**) of the top section (**10**) of the device. The PCB can be connected to the piezoelectric engine (**30**) via wires that run along a channel (**124**) in the bottom plate (**12**) of the top section of the device (**10**). The piezoelectric engine is controlled by the microprocessor, which is in turn

controlled by the user via a direct mechanism (e.g., button interface, touch screen, movement sensor, USB cable attached to a computer or smartphone, and so forth) or via a wireless mechanism (e.g., from an external controller such as a computer or smartphone connected to the device via Bluetooth, IEEE 802.11, and so forth). Information regarding the status of the device can be relayed to the user via a multiplicity of mechanisms, including, but not limited to, a segmented light-emitting diode (LED) display, a segmented liquid crystal display (LCD), an LCD, a touchscreen LCD, and/or via wired or wireless communication to an external device such as computer or smartphone. Regarding the wireless mechanism, the electronics of the device will include a transmitter to enable it to send and receive wireless signals. One preferred embodiment of the invention is able to send and receive signals using both Bluetooth and IEEE 802.11 standards in the 2.4, 3.6, 5 and 60 GHz frequency bands (Wi-Fi). This can allow the device to be controlled wirelessly, remotely, and securely e.g., via the Internet through a mobile smartphone communications network. In a preferred embodiment, the device may be controlled from a mobile smartphone via Bluetooth or Wi-Fi using a software application downloaded or purchased from an online application store. In another preferred embodiment, the device can also be turned off remotely using a wireless mechanism when operation of the device is not needed, e.g., if the device is located in a hotel room when the room is unoccupied.

[0031] With reference to FIG. **5**, the microprocessor is controlled via a direct mechanism that uses buttons (**215a** and **215b**) fitted into ports (**210a** and **210b**) in the middle section (**20**) to interface with switches (**222a** and **222b**) on the PCB (**220**), along with a display interface (**211** and **221**) and a USB connector (**212**) accessible via a port (**212a**) in the middle section (**20**) of the device. In a preferred embodiment, two buttons (**215a** and **215b**) are used in conjunction with a 7-segment light-emitting diode (LED) display (**221**) and a light pipe (**211**) fitted into a slot (**210**) in the middle section (**20**) to instruct the microprocessor to drive the invention according to the user's preference. When the device is in operation, two LEDs (**224a** and **224b**) will activate. A ring-shaped light diffuser (**24**) transmits the light emitted by these LEDs (**224a** and **224b**) as a glowing band around the perimeter of the device. The ring-shaped light diffuser (**24**) can be any colour and can be clear, partially opaque, frosted, or opaque. In a preferred embodiment, the ring-shaped light diffuser (**24**) is made of frosted glass or frosted clear plastic such as frosted polyethylene, frosted polycarbonate, and the like.

[0032] An example of the operation of a preferred embodiment is given here; note that this example is for illustrative purposes only, and by no means limits the functionality of device in any way whatsoever. Importantly, the use of the device and the interface parameters can be customised, altered, changed, updated, and modified at any time by changing or updating the microprocessor programme. In this illustrative example of a preferred embodiment, the user is able to turn the device on by holding the first button (**215a**, which activates switch **222a**) firmly for 3 seconds. The device is switched on when the 7-segment display (**221**, transmitted to the outside of the device via a light pipe, **211**, for the user to see) shows the characters 'o' and 'n' successively. When the device is on, the device can be turned off also by holding the first button (**215a**) firmly for 3 seconds, and the device is switched off after the 7-segment display (**221**) shows 'o', 'F', and 'F' successively. Once the device has been turned on, the user can set the run-time duration of the piezoelectric engine and the frequency of repeat run-time operations over a preconfigured time period, as set by the microprocessor programme. The user enters the device configuration mode by holding the second button (**215b**, which activates switch **222b**) for 2 seconds, after which the 7-segment display (**221**) shows 'C'. The user is then able to set the operation of the piezoelectric engine by pressing the first button (**215a**), which cycles through three preset parameters, as shown on the 7-segment display: 't' for oil type, 'L' for strength level, and 'd' for duration, all of which are settings that modify the run-time duration of the piezoelectric engine and time intervals between piezoelectric engine operations. When the 7-segment display (**221**) shows 't' for oil type, the user can press the second button (**215b**) to select a preset active material liquid type on the basis of viscosity, numbered '1' to '4' as displayed on the 7-segment display (**221**). This setting configures the run-time duration of the piezoelectric engine, e.g. with a setting of '1', the piezoelectric engine operates for 2 seconds, which is enough time to aspirate a lower-viscosity (e.g., viscosity between 0.5 to 1 centipoise) active material fluid, whereas a setting of '4' operates the piezoelectric engine for 5 seconds, which is enough time to aspirate a higher-viscosity (e.g., viscosity between 3 to 4 centipoise) active material fluid. The user can move to the next setting, 'L' for strength, by pressing the first button (**215a**). When the 7-segment display (**221**) shows 'L' for oil type, the user can then press the second button (**215b**) to select a preset odour strength of the active material liquid, indicated by '_' for low odour, '=' for a stronger odour, and 'Ξ' for the strongest odour, as displayed on the 7-segment display (**221**). This setting configures the number of pulses at which the piezoelectric engine will operate using the prior 't', or oil type, setting, e.g. with a setting of '_', the piezoelectric engine operates for at the 't'

level every 20 seconds over a 60-second period, whereas a setting of 'Ξ' operates the piezoelectric engine at the 't' level for every 10 seconds over a 60-second period. The user can move to the next setting, 'd' for duration, by pressing the first button (**215a**). When the 7-segment display (**221**) shows 'd' for duration, the user can then press the second button (**215b**) to select a preset duration for the operation of the device, indicated by '1', '2', '3', '4', and '8' on the 7-segment display (**221**) for the number of hours the device will operate using the programmed configuration, or the figure '-' shown on the 7-segment display (**221**) for continuous operation. Once the user has set these configuration parameters, the user can press the first button (**215a**) for 3 seconds, at which time the 7-segment display (**221**) will show 'E', indicating that the device has exited the configuration mode and will now run, as defined by the parameters entered by the user, when the second button (**215b**) is pressed. Additionally, to confirm the device is running when the second button (**215b**) is pressed, the 7-segment display (**221**) will show three ascending lines, '_', then '=', then 'Ξ' - on the 7-segment display (**221**) once, and then a red dot on the 7-segment display (**221**) will pulse every 5 seconds until the user either interacts with the second button (**215b**) to change the device settings as described above, or the device is turned off using the first button (**215a**) as described earlier.

[0033] Again note that the above example is illustrative only, and no limitation is imposed on the customisation of the device and the interface with the device in this information. In another embodiment, the user can interface with the device via the USB connector (**212**) accessible via a port (**212a**) in the middle section (**20**) of the device, and can instruct the device to function similar to what is described in the illustrative example using an external controller such as a computer, smartphone, and other such controlling apparatus. In another further embodiment, the microprocessor and/or the PCB are capable of wireless communication via Bluetooth, Wi-Fi, and/or other such means. As such, similar functions as described in the illustrative example can be performed on the invention wirelessly.

[0034] With reference to FIGS. **2** and **5**, the invention includes an electrical power supply to enable it to function. This may be contained within the device or this may comprise an external plug that can be connected to an external electrical power source such as a household power socket via a plug extending from the device. Alternatively, the power source can be via the USB connector (**212**), accessible via a port (**212a**) in the middle section (**20**) of the device, which interfaces with the PCB (**220**). In one preferred embodiment, the source of power is

internal, and comprises one or more batteries, e.g., dry cell batteries such as 'AA' batteries, 'AAA' batteries, 'D' batteries, watch batteries, or rechargeable batteries such as lithium ion batteries, lithium polymer batteries, and so forth. In a more preferred embodiment, the power source is a lithium polymer battery (**223**).

[0035] With reference to FIGS. **1** to **5**, the invention comprises the housing (**10**, **20**, and **23**) that contains all components, including piezoelectric engine, electronics, active material reservoir container, and mounting components thereof. In various embodiments, the housing is comprised of separate component layers. In a preferred embodiment, the housing is comprised of three sections, including a top section (**10**) housing the piezoelectric engine and mountings, a middle section (**20**) housing the electronics, power source, and active material reservoir container when attached, and a bottom housing section (**23**), or bottom cap, enclosing the device from the bottom and supporting the active material reservoir container. In a preferred embodiment, the middle section (**20**) also features a sleeve (**214**) for the active material reservoir container, which is accommodated by and slots into a cavity (**122**) feature of the bottom plate (**12**) of top section (**10**). The housing and/or various housing components can be made of a thermoplastic material such as polypropylene, polycarbonate, polyethylene terepthalate, and so forth, and be injection molded. Alternatively, the housing may be made of metal such as stainless steel or aluminium or the like. In various embodiments, a combination of thermoplastic materials and metal materials can be used to construct the housings, for which the various components of the housing are connected. In other embodiments, the housings can be encased by shell materials that are designed to fit over the assembled device housings. In a preferred embodiment, the device comprises an inner housing made of a thermoplastic material that is sleeved by a metal shell that encases the thermoplastic material inner housing.

[0036] With reference to FIGS. **1** to **5**, any connecting means can be used to connect the different housing components together, including, but not limited to, screws, magnets, adhesives, rivets, clips, welding, and so forth, along with combinations thereof. In a preferred embodiment, the top section of the housing is connected to the middle section of the housing (**20**) using screws (**113a** and **113b**). The screws are attached to posts (**110a** and **110b**) that stem from the top section of the housing (**10**) into ports (**213a** and **213a**) from the middle section of the housing (**20**). In the same embodiment, the bottom section (**23**) is attached to

the middle section of the housing (**20**) via magnets (**231a**, **231b**, **232a**, and **232b**), two of which (**232a** and **232b**) are glued into posts (**230a** and **230b**) on the bottom section (**23**), and two of which (**231a** and **231b**) are glued onto the bottom of the middle section of the housing (**21**).

[0037] With reference to FIGS. **8** to **11**, an embodiment is given comprising multiple diffusing systems, specifically three diffusing systems, in one device, hereafter referred to as the multi-system embodiment or multi-system device. There are design and systemic similarities between the single diffusing system embodiment of FIGS. **1** to **7** and the multi-system embodiment of FIGS. **8** to **11**, namely that the diffusion device (FIG. **8**) incorporates a top section (**50**) housing the diffusing engine and associated components, a middle section (**60**) housing the active material reservoir containers, controlling circuitry, and power source, and a bottom section (**61**) that supports the active material reservoir containers and enclose the device. The multi-system embodiment can use the same active material reservoir containers (**40**) of the single system embodiment.

[0038] In the multi-system embodiment shown in FIGS. **8** to **11**, the top section (**50**, and FIGS. **9** and **10**) of the invention houses three piezoelectric diffusing engines (**53a**, **53b**, and **53c**), and includes the last stage of active material delivery components (**70a**, **70b**, and **70c**) along with ring-shaped magnetic docking components (**54a**, **54b**, and **54c**). The bottom section of the device (**60**, **61**, and FIG. **11**) can house up to three active material reservoir containers (FIG. **6**, containers not shown in FIG. **11**) in sleeved ports (**601a**, **601b**, and **601c**). The middle section of the device (**60**, **61**, and FIG. **11**) also houses components for powering the device using external power via USB (**623**) that is accessible via a port (**604**) in the middle section (**60**) of the device, and/or using an internal battery (**63**), as well as components for controlling the device using a microprocessor on a PCB (**62**), either via a direct mechanism using buttons (**626a** to **626d)** and 7-segment display (**621**, transmitted to the user via a light pipe, **625**) or via an indirect mechanism such as Bluetooth, Wi-Fi, and so forth.

[0039] With reference to FIG. **9**, **10**, and **11**, the top section (**50**) of the multi-system embodiment comprises a top plate (**51**) and a bottom plate (**52**). The top plate (**51**) encloses three piezoelectric engines (**53a**, **53b**, and **53c**), which are in turn placed in cavities (**551a**, **551b**, and **551c**) set into the bottom plate (**52**) of the top section (**50**). The piezoelectric

engines are each mounted using top O-rings (**531b**, **531d**, and **531e**) and bottom O-rings (**531a**, **531c**, and **531f**). The O-rings can be comprised of the same materials as described for the single system embodiment shown in FIGS. **1** to **5** and described earlier. The piezoelectric engines are connected via wires (not shown) to the PCB (**62**), which is mounted in the middle section (**60**), through a rectangular gap (**591**) in the bottom plate (**52**). The wires (not shown) run along a channel of the bottom plate (**52**) and are secured by wire clips in the channel (**58a** to **58d**). With reference to FIGS. **9**, **10**, and **11**, the top and bottom plates are joined together by posts (**541a** and **541b**) that slot into ports (**572a** and **572b**) in the bottom plate (**52**), and are attached to the middle section of the housing (**60**) by screws (**613a** and **613b**) that are fitted through posts (**605a** and **605b**) in the middle section of the housing. In addition, the bottom plate (**52**) of the top section (**50**) of the multi-system embodiment also includes clips (**571a** to **571f**) that connect the top section and the middle section of the housing more securely. These clips (**571a** to **571f**) are attached to slots (**606a** to **606f**; note that **606a**, **606d**, **606e**, and **606f** are represented with dashed lines as they are obscured by the oblique view of FIG. **11**) in the middle section to ensure a tight fit between the top and middle sections.

[0040] With reference to FIG. **10**, the last stages of the active material delivery mechanisms of the multi-system embodiment comprise three rigid, porous, hydrophilic, and oleophilic wicks (**70a**, **70b**, and **70c**) that fit into ports (**56a**, **56b**, and **56c**) on the bottom plate (**52**) of the top section (**50**). The rigid, porous oleophilic, and hydrophilic wicks are designed in the same way and are comprised of the same materials as described for the single system embodiment shown in FIGS. **1** to **5**. The last stage delivery mechanisms also comprise magnetic docking mechanisms for active material reservoir containers (**40**) to interface with the last stage delivery components, and uses ring-shaped magnets (**54a**, **54b**, and **54c**) that slot into cavities (**55a**, **55b**, and **55c**) on the bottom plate (**52**) of the top section (**50**) of the device. This magnetic docking mechanism is similar to the docking mechanism of the single system embodiment shown in FIGS. **1** to **5**.

[0041] With reference to FIGS. **8**, **10** and **11**, the middle section of the multi-system embodiment (**60**) houses the electronics, power source, and active material reservoir containers when attached, and a bottom section (**61**), or bottom cap, enclosing the device from the bottom and supporting the active material reservoir containers. The middle section (**60**) also features three sleeves (**601a**, **601b,** and **601c**) for three active material reservoir

containers, which are accommodated by and slot into cavities (**551a**, **551b**, and **551c**) on the bottom plate (**52**) of top section (**50**). With reference to FIGS. **10** and **11**, the PCB is mounted vertically along the back face of the middle section (**60**) of the device, and is supported by a placeholder (**592**) in the bottom plate (**52**) of the top section (**50**) of the device. The PCB (**62**) features a microprocessor that can be controlled via a direct mechanism using buttons (**626a** to **626d**), fitted into ports (**603a** to **603d**) in the middle section (**60**), that interface with the PCB (**62**) via switches (**622a** to **622d**), along with a display interface comprised of a 7-segment display (**621**) and a light pipe (**625**), both of which fit into a slot (**602**) of the middle section (**60**). The PCB also has a USB connector (**623**) that is accessible via a port (**604**) in the middle section (**60**) of the device. As with the single system embodiment, when the device is in operation, two LEDs (**624a** and **624b**) will activate. A triangular-shaped light diffuser (**610**) transmits the light emitted by these LEDs (**624a** and **624b**) as a glowing band around the perimeter of the device. As with the single system embodiment, the ring-shaped light diffuser (**610**) can be made of frosted glass or frosted clear plastic such as frosted polyethylene, frosted polycarbonate, and the like. With reference to FIG. **11**, the multi-system embodiment includes an electrical power supply to enable it to function, which can be provided via the USB connector (**623**) that interfaces with the PCB (**62**) and is accessible via a port (**604**) in the middle section (**60**) of the device, or via a lithium polymer rechargeable battery (**63**). With further reference to FIG. **11**, the bottom section (**61**), or bottom cap, is attached to the middle section (**60**) via magnets (**611a** and **611b**), one of which (**611b**) is glued into a post (**612**) on the bottom section (**61**), and the other of which (**611a**) is glued onto the bottom of the middle housing (**60**).

[0042] Regarding the operation of the multi-system embodiment, the device can be operated in a manner similar to that described in the example given for the single system embodiment. With reference to FIGS. **9**, **10**, and **11**, an example of the operation of the multi-system embodiment is given here; note that this example is for illustrative purposes only, and by no means limits the functionality of device in any way whatsoever. Importantly, the use of the device and the interface parameters can be customised, altered, changed, updated, and modified at any time by changing or updating the microprocessor programme. In this illustrative example of a preferred embodiment, the user is able to turn the device on by holding the bottom button (**626d**, which activates switch **622d**) firmly for 3 seconds. The device is switched on when the 7-segment display (**621**, transmitted to the outside of the

device via a light pipe, **625**, for the user to see) shows the characters 'o' and 'n' successively. When the device is on, the device can be turned off also by holding the bottom button (**626a**) firmly for 3 seconds, and the device is switched off after the 7-segment display (**621**) shows 'o', 'F', and 'F' successively. Once the device has been turned on, the user can set the run-time duration of each of the three piezoelectric engines and the frequency of repeat run-time operations of each engine over a preconfigured time period, as set by the microprocessor programme. The configuration of each piezoelectric engine can be addressed by one of the top three buttons (**626a**, **626b**, and **626c**), with each button corresponding to an individual piezoelectric engine, i.e., button **626a** corresponds to piezoelectric engine **53c**, button **626b** corresponds to piezoelectric engine **53a**, and **626c** corresponds to piezoelectric engine **53b**. The user enters the configuration mode for each piezoelectric engine by holding the respective button, after which the 7-segment display (**621**) shows 'C' for the corresponding engine. The user is then able to set the operation of the selected piezoelectric engine as described in the illustrative example given for the single system embodiment, the details of which were given prior. Once the user has set the configuration parameters for the selected piezoelectric engine, the user can press the corresponding button for 3 seconds, at which time the 7-segment display (**621**) will show 'E', indicating that the device has exited the configuration mode for that piezoelectric engine, which will now run, as defined by the parameters entered by the user, when the corresponding button is pressed. Additionally, to confirm the device is running when the bottom button (**626d**) is pressed, the 7-segment display (**621**) will show three ascending lines, '_', then '=', then 'Ξ' - on the 7-segment display (**621**) once, and then a red dot on the 7-segment display (**621**) will pulse every 5 seconds until the user either interacts with the button corresponding to the active piezoelectric engine to change the device settings as described above, or the device is turned off using the bottom button (**626d**) as described earlier.

[0043] As with the single system embodiment, note that the above example is illustrative only, and no limitation is imposed on the customisation of the multi-system embodiment and the interface with the device in this information. In alternative embodiments, the user can interface with the device via the USB connector (**623**), and can instruct the device to function similar to what is described in the illustrative example using an external controller such as a computer, smartphone, and other such controlling apparatus. In another further embodiment, the microprocessor and/or the PCB are capable of wireless communication via Bluetooth, Wi-

Fi, and/or other such means. As such, similar functions as described in the illustrative example can be performed on the invention wirelessly.

[0044] As with the single system embodiment of FIGS. **1** to **5**, the housing and/or various housing components of the multi-system embodiment (FIG. **8**) can be made of materials as described for the single system embodiment e.g., a thermoplastic material such as polypropylene, polycarbonate, polyethylene terepthalate, and so forth, or a metal such as stainless steel or aluminium or the like. As with the single system embodiment, a combination of thermoplastic materials and metal materials can be used to construct the housings, for which the various components of the housing are connected. Additionally, the housings can be encased by shell materials that are designed to fit over the assembled device housings e.g., the device can comprise an inner housing made of a thermoplastic material that is sleeved by a metal shell that encases the thermoplastic material inner housing.

[0045] In conclusion, the portable diffuser device of the present invention enables the diffusion and aspiration of active materials, with particular regards to liquid active materials, as aerosols using a piezoelectric engine, or, in the case of a multi-system device, multiple piezoelectric engines. The invention incorporates a method to easily add or remove active material reservoir containers, and also utilises a novel, staged method for the delivery of the active material to the piezoelectric engine, or respective piezoelectric engines in the case of a multi-system device, for dispersion. Furthermore, the invention incorporates a direct interface mechanism and/or a wireless interface mechanism, allowing the user to control the device via a multiplicity of mechanisms, including but not limited to, a button interface, a display interface, a Bluetooth interface via an external wireless device such as a smartphone or computer, or a Wi-Fi interface via an external device such as a smartphone or computer. Note that, although particular embodiments of the invention have been described in detail in this application for the purposes of providing illustrative examples, any modifications and enhancements that can or may be made to the invention are assumed to remain within the spirit and scope of the invention. Furthermore, in view of this description in its entirety, it will be apparent to those skilled in the art that numerous modifications can be made; consequently, this illustrative description is presented for the purpose of enabling those skilled in the art to construct and use the invention as required. The exclusive rights to all modifications which come within the scope of the appended claims are reserved.

[0046] Note that the content of documents referred to in this application are for information only, and are not incorporated by reference to this application.

CLAIMS

1. An active material dispersion device comprising:

a) a top section, housing **one** active material dispersion engine and an active material delivery mechanism to the dispersion engine;

b) a middle section, featuring a sleeve for housing **one** active material reservoir container and driving electronics for the active material dispersion engine, as well as active material delivery stages, upon which the top portion can be placed and interface with the middle portion;

c) an active material reservoir container that contains the active material, as well as the necessary components of the active material delivery stages required for delivery of the active material to the dispersion engine;

d) a bottom section that encloses the middle section and thus the device, and supports the active material reservoir containers when they are attached to the device.

2. The dispersion device of claim **1**, whereby a dispersing engine is mounted between the two plates of the top section and atop the last stage of the active material delivery mechanism, for which the mounts are toric rings, or O-rings, comprised of a material that has a Shore A hardness of between 45 and 55.

3. The dispersion device of claim **2**, where the dispersion engine is a piezoelectric engine comprised of a porous metal mesh enclosed by a piezoelectric ceramic material, whereby a voltage can be applied to the piezoelectric ceramic material and cause the ceramic to vibrate at ultrasonic frequencies, and disperse any active material that is either in contact with or near contact to the porous metal mesh.

4. The dispersion device of claim **2**, where the dispersion engine is in contact with or very near to the last stage of the active material delivery mechanism, comprising a rigid, porous, oleophilic, and hydrophilic wick made of polyethylene fibre.

5. The dispersion device of claim **2**, where the bottom plate of the top section contains a ring magnet for docking with other stages of the active material delivery mechanism.

6. The dispersion device of claim **1**, where the middle section of the housing contains a printed circuit board, or PCB, that features circuitry, including microprocessor, and a rechargeable lithium polymer battery to supply power to the circuitry and to the piezoelectric engine for the driving of the piezoelectric engine housed in the top section of the device as described in claims **2** to **5**.

7. The dispersion device of claim **6**, where the middle section of the housing further features a direct mechanism for user interface with the device, comprising a seven-segment display and two buttons, whereby the user can programme the dispersion device following the settings provided by the microprocessor on the PCB, as well as a USB interface for programming of the device and charging of the rechargeable lithium polymer battery detailed in claim **6**.

8. The dispersion device of claim **6**, where the PCB and circuitry, including microprocessor, feature components that enable the user to interface with the device via an indirect mechanism such as Bluetooth and Wi-Fi.

9. The dispersion device of claim **1**, where an active material reservoir container is a container of a certain volume made of glass, plastic, or metal, and can be fit into the housing via a sleeve as described in claim **1**.

10. The dispersion device of claim **9**, where the active material reservoir container also features components of the active material delivery mechanism, including a soft, hydrophilic, and oleophilic wick made of polyethylene, that fits into the bottle and delivers active material to the last stage of the active material delivery mechanism described in claim **4**.

11. The dispersion device of claim **10**, where the active material reservoir container features a cap through which the soft, hydrophobic, and oleophilic wick can fit through and thus interface directly through contact with the last stage of the active material delivery mechanism described in claim **4**.

12. The dispersion device of claim **10**, where the cap component of the active material reservoir container further features a rubber- or polymer-coated washer that interfaces with and magnetically docks to the top section of the dispersion device as described in claim **5**, providing good contact with the last stage of the delivery mechanism and sealing the interface between the active material reservoir container and the docking portion of the device.

13. The dispersion device of claim **1**, where the bottom section of the device features two magnets mounted on posts that dock with two magnets attached to the bottom of the middle section of the device, thus supporting the active material reservoir container and fully enclosing the device.

14. An active material dispersion device comprising:

a) a top section housing **three** active material dispersion engines, each with their own

components for their respective active material delivery mechanisms;

b) a middle section featuring **three** sleeves for housing active material reservoir containers, allowing for up to three active material reservoir containers to be placed within and be used by the device, as well as driving electronics for the active material dispersion engines and active material delivery stages, upon which the top portion can be placed and interfaced with;

c) a bottom section that encloses the middle portion and thus the device, along with any active material reservoir containers when they are attached to the device.

15. The dispersion device of claim **14**, where the top section is comprised of two plates that are connected by posts fitted through ports in the bottom plate, as well as clips that extend from the side of the top plate, and attached to the middle section via screws that are fitted through posts in the middle section, and slots for the clips.

16. The dispersion device of claim **15**, where **three** dispersing engines are mounted between the two plates of the top section and atop the last stage of the active material delivery mechanism, whereby the mounts for each of the dispersing engines are toric rings, or O-rings, comprised of a material that has a Shore A hardness of between 45 and 55.

17. The dispersion device of claim **15**, where the dispersion engines are identical to the dispersion engines described in claim **3**.

18. The dispersion device of claim **15**, where the dispersion engines are in contact with or very near to the last stage of the active material delivery mechanism for each dispersion engine, comprising rigid, porous, oleophilic, and hydrophilic wicks made of polyethylene fibre.

19. The dispersion device of claim **15**, where the bottom plate of the top section contains a ring magnet at each of the three last stage delivery mechanisms, for docking with other stages of the active material delivery mechanism.

20. The dispersion device of claim **14**, where the middle section of the housing contains a printed circuit board, or PCB, that features circuitry, including microprocessor, and a rechargeable lithium polymer battery to supply power to the circuitry and to the piezoelectric engines for the driving of the piezoelectric engines housed in the top section of the device as described in claims **15** to **18.**

21. The dispersion device of claim **20**, where the middle section of the housing features a direct mechanism for user interface with the device, comprising a seven-segment display and four buttons, whereby the user can programme each dispersion engine of the device

following the settings provided on the microprocessor on the PCB, as well as a USB interface for programming of the device and charging of the rechargeable lithium polymer battery detailed in claim **20**.

22. The dispersion device of claim **20**, where the PCB and circuitry, including microprocessor, feature components that enable the user to interface with the device via an indirect mechanism such as Bluetooth and Wi-Fi.

23. The dispersion device of claim **14**, where the bottom section of the device features one magnet mounted on a post that docks with a magnet attached to the bottom of the middle section of the device, thus supporting the active material reservoir containers placed within the device and fully enclosing the device.