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Microfluidic delivery system and cartridge having an outer cover

US 9636430 B2

ABSTRACT

A cartridge for a microfluidic delivery system is defined by a longitudinal axis. The cartridge includes a reservoir for containing a fluid composition. The cartridge also includes a nozzle operatively connected with the reservoir. The nozzle is in fluid communication with the reservoir for releasing the fluid composition. The cartridge includes an outer cover operatively connected with the reservoir. The outer cover comprises an orifice that is adjacent to the nozzle. An air flow path is formed by a gap between the reservoir and the outer cover.

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DESCRIPTION

FIELD

The present disclosure generally relates to systems for delivering a fluid composition into the air, and, more particularly, relates to microfluidic delivery systems and cartridges for delivering fluid compositions into the air using a die.

BACKGROUND

Various systems exist to deliver fluid compositions, such as perfume compositions, into the air by energized (i.e. electrically/battery powered) atomization. In addition, recent attempts have been made to deliver fluid compositions, such as perfume compositions, into the air using microfluidic delivery technology such as thermal and piezo inkjet heads.

When using microfluidic delivery technology to deliver fluid compositions, especially when delivering the fluid compositions into the air, proper fill of the atomized fluid composition into the surrounding space may be important.

One method used to increase room fill includes the use of a fan in combination with a microfluidic delivery device, such a thermal or piezo inkjet head. A fan may be placed on the opposite side of the inkjet head from where the fluid composition is dispensed to help force the fluid composition into the air. However, even with the use of a fan, there is still a need for increased air flow to help deliver the atomized fluid composition into the air with sufficient force to fill a room. Higher powered fans can be to provide increased air flow, but would increase the energy consumption of the device.

Thus, it would be beneficial to provide a device that delivers atomized fluid composition into the air with sufficient force to fill a room or space with the fluid composition.

SUMMARY

Aspects of the present disclosure include a cartridge for a microfluidic delivery system. The cartridge has a longitudinal axis. The cartridge comprises a reservoir for containing a fluid composition. The cartridge comprises a nozzle

CLAIMS (20)

What is claimed is:

1. A cartridge for a microfluidic delivery system, the cartridge having a longitudinal axis and comprising:

a reservoir for containing a fluid composition;

a nozzle operatively connected with the reservoir, wherein the nozzle is in fluid communication with the reservoir for releasing the fluid composition;

an outer cover operatively connected with the reservoir, the outer cover comprising an orifice that is adjacent to the nozzle, wherein an air flow path is formed by a gap between the reservoir and the outer cover.

2. The cartridge of claim 1, wherein the reservoir comprises a top portion, a base portion opposing the top portion, and at least one sidewall extending between and connecting the top and base portions, wherein the outer cover comprises a top and a skirt extending from the top, wherein the top comprises the orifice of the outer cover, and wherein the gap is disposed between the skirt and the sidewall of the reservoir, and wherein at least a portion of the air flow path between the skirt and the sidewall extends longitudinally.

3. The cartridge of claim 1, wherein the orifice and the nozzle are at least partially longitudinally aligned.

4. The cartridge of claim 1 further comprising a die in fluid communication with the reservoir, wherein the die comprises the nozzle.

5. The cartridge of claim 4, wherein the die comprises a heater.

6. The cartridge of claim 4, wherein the die comprises a piezoelectric crystal.

7. The cartridge of claim 4, wherein the die comprises nozzle plate, wherein the orifice is defined by a surface area wherein the surface

with the reservoir for releasing the fluid composition. The cartridge comprises an outer cover operatively connected with the reservoir. The outer cover comprises an orifice that is adjacent to the nozzle. An air flow path is formed by a gap between the reservoir and the outer cover.

Aspects of the present disclosure also include a cartridge for a microfluidic delivery system. The cartridge has a longitudinal axis. The cartridge comprises a reservoir for containing a fluid composition. The reservoir comprises a top portion, a base portion opposing the top portion, and at least one sidewall extending between and connecting the top and base portions. The cartridge comprises a nozzle operatively connected with the reservoir. The nozzle is in fluid communication with the reservoir for releasing the fluid composition. The cartridge comprises an outer cover operatively connected with the reservoir. The outer cover comprises a top and a skirt that extends from the top of the outer cover and at least partially overlaps with the sidewall of the reservoir along the longitudinal axis. The top of the outer cover comprises an orifice. An air flow path is formed between the outer cover and the reservoir and extends from the skirt to the orifice.

Aspects of the present disclosure also include a cartridge for a microfluidic delivery system. The cartridge comprises a reservoir containing a fluid composition to be dispensed from at least one nozzle. The cartridge also comprises an outer cover connected with the reservoir. The outer cover has a top with an orifice disposed adjacent to the nozzle and a skirt extending from the top. At least one of the reservoir and the outer cover comprising electrical contacts that are electrically connectable with the microfluidic delivery system.

Aspects of the present disclosure also include a microfluidic delivery system comprising a housing having a base, at least one sidewall connected with the base, and an opening for receiving a cartridge at least partially within the housing. The housing comprises an air inlet. The microfluidic delivery system comprises a fan in fluid communication with the housing and a cartridge releasably and electrically connectable with the housing. The cartridge has a longitudinal axis. The cartridge comprises a reservoir containing a fluid composition to be dispensed from at least one nozzle. The cartridge also comprises an outer cover connected with the reservoir. The outer cover has a top with an orifice disposed adjacent to the nozzle and a skirt extending from the top. The outer cover comprises an orifice that is disposed adjacent to the nozzle. An air flow path is formed by a gap between the reservoir and the outer cover.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a microfluidic delivery system including a housing having a cartridge disposed therein and a charger for recharging rechargeable batteries used to power the microfluidic delivery system.

FIG. 2 is a perspective view of the housing of the microfluidic delivery system of FIG. 1 without a charger or cartridge connected therewith.

FIG. 3 is a sectional view of FIG. 2 taken along line 3-3.

FIG. 4 is a bottom, plan view of the housing of FIG. 2.

FIG. 5 is a schematic, perspective view of a housing having a cartridge disposed therein, and comprising a door for accessing the interior of the housing.

FIG. 6 is a perspective view of a cartridge having a reservoir and an outer cover.

FIG. 7 is a sectional view of FIG. 6 taken along line 7-7.

FIG. 8 is a sectional view of FIG. 6 taken along line 8-8.

FIG. 9 is a perspective view of a cartridge with an outer cover removed to make visible a reservoir having a microfluidic delivery member with a semi-flex printed

8. The cartridge of claim 1, wherein fluid composition dispensed from the nozzle combines with air traveling through the air flow path, wherein the combined fluid composition and air exit the cartridge at the orifice.

9. The cartridge of claim 1, wherein the air flow path is defined by a width extending between the outer cover and the reservoir, wherein the width is at least 2 millimeters.

10. A cartridge for a microfluidic delivery system, the cartridge having a longitudinal axis and comprising:

a reservoir for containing a fluid composition, the reservoir comprising a top portion, a base portion opposing the top portion, and at least one sidewall extending between and connecting the top and base portions;

a nozzle operatively connected with the reservoir, wherein the nozzle is in fluid communication with the reservoir for releasing the fluid composition; and

an outer cover operatively connected with the reservoir, wherein the outer cover comprises a top and a skirt that extends from the top of the outer cover and at least partially overlaps with the sidewall of the reservoir along the longitudinal axis, wherein the top of the outer cover comprises an orifice, wherein an air flow path is formed between the outer cover and the reservoir and extends from the skirt to the orifice.

11. The cartridge of claim 10, wherein at least a portion of the air flow path extends axially.

12. The cartridge of claim 10 further comprising a die operatively connected with the reservoir, wherein the die comprises the nozzle.

13. The cartridge of claim 12, wherein the die comprises a heater.

14. The cartridge of claim 12, wherein the die comprises a piezoelectric crystal.

15. The cartridge of claim 10, wherein the air flow path is defined by a width extending between the outer cover and the reservoir, wherein the width is at least 2 millimeters.

16. The cartridge of claim 10, wherein the cartridge is electrically connectable with the microfluidic delivery system.

17. A cartridge for a microfluidic delivery system, the cartridge comprising:

a reservoir containing a fluid composition to be dispensed from at least one nozzle, and

an outer cover connected with the reservoir, the outer cover having a top with an orifice disposed adjacent to the nozzle and a skirt extending from the top, wherein at least one of the reservoir and the outer cover comprising electrical contacts that are electrically connectable with the microfluidic delivery system.

18. A microfluidic delivery system comprising:

a housing having a base, at least one sidewall connected with the base, and an opening for receiving a cartridge at least partially within the housing, wherein the housing comprises an air inlet;

a fan in fluid communication with the housing;

a cartridge releasably and electrically connectable with the housing, wherein the cartridge has a longitudinal axis, the cartridge comprising a reservoir containing a fluid composition to be dispensed from at least one nozzle, and

FIG. 10 is a schematic, sectional view of a cartridge with an outer cover removed to make visible a reservoir having a microfluidic delivery member with a rigid PCB connected therewith.

FIG. 11 is a sectional view of FIG. 6 taken along line 11-11.

FIG. 12 is a bottom, plan view of the cartridge of FIG. 6

FIG. 13 is an enlarged view of portion 13 of FIG. 7.

FIG. 14A is a top, perspective view of a microfluidic delivery member having a rigid PCB.

FIG. 14B is a bottom, perspective view of a microfluidic delivery member having a rigid PCB.

FIG. 15A is a perspective view of a semi-flex PCB for a microfluidic delivery member.

FIG. 15B is side, elevation view of a semi-flex PCB for a microfluidic delivery member.

FIG. 16 is an exploded view of a microfluidic delivery member.

FIG. 17 is a top, perspective view of a die of a microfluidic delivery member.

FIG. 18 is a top, perspective view of a die with a nozzle plate removed to show fluid chambers of the die.

FIG. 19 is a top, perspective view of a die with layers of the die removed to show the dielectric layer of the die.

FIG. 20 is a sectional view of FIG. 17 taken along line 20-20.

FIG. 21 is an enlarged view of portion 21 taken from FIG. 20.

FIG. 22 is a sectional view of FIG. 17 taken along line 22-22.

FIG. 23 is a sectional view of FIG. 17 taken along line 23-23.

FIG. 24 is a sectional view of a portion of a fluid path of a microfluidic delivery member.

DETAILED DESCRIPTION

The present disclosure provides a microfluidic delivery system comprising a cartridge having a microfluidic delivery member and methods for delivering fluid compositions into the air.

The microfluidic delivery system of the present disclosure may include a housing and a cartridge. The cartridge may be fixed with the housing, removably connectable with the housing, and/or replaceable, and may be disposed at least partially within the housing. The cartridge may comprise a reservoir for containing a volatile composition, a microfluidic delivery member, and a fluid transport member disposed within the reservoir and configured to deliver a fluid composition from within the reservoir to the microfluidic delivery member. The microfluidic delivery member may be configured to dispense the fluid composition into the air. The cartridge is electrically connectable with the housing.

The reservoir may be defined by a top portion, a base portion, and a sidewall(s) connecting and extending between the top portion and the base portion. The microfluidic delivery member may be connected with the reservoir.

The cartridge may include an outer cover. The outer cover may be defined by an interior and an exterior. The outer cover may include a top that is defined by a perimeter. The top includes an orifice. The top of the outer cover may substantially cover the top portion of the reservoir. The orifice may be disposed adjacent to the die, and, for example, may be at least partially aligned, or fully aligned therewith. The outer cover is connected with the reservoir such that a gap is formed between the outer cover and the reservoir, forming an air flow path between the outer cover and the reservoir.

The outer cover may include a skirt that extends from the perimeter of the top toward the reservoir. The skirt may surround at least a portion of the sidewall(s) of the reservoir. The skirt may be configured such that air is able to flow longitudinally adjacent to the sidewall(s) of the reservoir. The air flow path preferably extends around all or most all of the reservoir. For example, it may be desirable for the air flow path to extend at least about 300 degrees around the reservoir, about 350 degrees about the reservoir, or about 360 degrees about the reservoir.

While the below description describes the microfluidic delivery system comprising a housing and a cartridge, both having various components, it is to be understood that the microfluidic delivery system is not limited to the construction and arrangement set forth in the following description or illustrated in the drawings. The microfluidic delivery system and cartridge of the present disclosure are applicable to other configurations or may be practiced or carried out in various ways. For example, the components of the housing may be located on the cartridge and vice-versa. Further, the housing and cartridge may be configured as a single unit versus constructing a cartridge that is separable from the housing as

the top, the outer cover comprising an orifice that is disposed adjacent to the nozzle, wherein an air flow path is formed by a gap between the reservoir and the outer cover.

19. The microfluidic delivery system of claim 18, wherein when the cartridge is connected with the housing, the cartridge is in fluid communication with the housing.

20. The microfluidic delivery system of claim 18 further comprising a die in fluid communication with the reservoir, wherein the die comprises the nozzle and a heater for volatilizing the fluid composition.

composition into the air or onto a target surface.

Housing

With reference to FIGS. 1-3, the microfluidic delivery system **10** may include a housing **12**. The housing **12** may be constructed from a single component or have multiple components that are combined to form the housing **12**. The housing **12** may be defined by an interior **21** and an exterior **23**. The housing **12** may be comprised of an upper portion **14**, a lower portion **16**, and a body portion **18** that extends between and connects the upper portion **14** and the lower portion **16**.

The housing **12** may include an opening **20** in the upper portion **14** of the housing **12** and a holder **24** for receiving and holding the cartridge **26** in the housing **12**. The cartridge **26** may be received into the upper portion **14** of the housing **12**. An air flow channel **34** may be formed between the holder **24** and the upper portion **14** of the housing **12**. With reference to FIG. 4, the housing **12** may comprise one or more air inlets **27**. The air inlets **27** may be positioned in the lower portion **16** of the housing, as shown in FIG. 4 for illustrative purposes only, or may be formed in the body portion **18** of the housing.

The microfluidic delivery system **10** may comprise a fan **32** to assist in driving room-fill and/or to help avoid deposition of larger droplets from landing on surrounding surfaces of the device that could damage the surface. The fan **32**, for example, may be disposed at least partially within the interior **21** of the housing **12** and may be positioned between the holder **24** and the lower portion **16** of the housing **12**. However, the fan may be configured and arranged in any other way suitable for the desired use. An exemplary fan includes a 5V 25×25×8 mm DC axial fan (Series 250, Type255N from EBMPAPST), that is capable of delivering about 10 to about 50 liters of air per minute (l/min), or about 15 l/min to about 25 l/min. As will be discussed in more detail below, the fan **32** pulls air from the air inlet(s) **27** into the housing **12** and directs the air up through the air flow channels **34** toward the cartridge **26**. The air velocity exiting the opening **20** may be in the range of about 1 meter per second (m/s) to about 5 m/s, or about 1.5 m/s to about 2.5 m/s.

The microfluidic delivery system **10** may be in electrical communication with a power source. The power source may be located in the interior **21** of the housing **12**, such as a disposable battery or a rechargeable battery. Or, the power source may be an external power source such as an electrical outlet that connects with a power cord **39** connected with the housing **12**. The housing **12** may include an electrical plug that is connectable with an electrical outlet. The microfluidic delivery system may be configured to be compact and easily portable. As such, the power source may include rechargeable or disposable batteries. The microfluidic delivery system may be capable for use with electrical sources as 9-volt batteries, conventional dry cells such as "A", "AA", "AAA", "C", and "D" cells, button cells, watch batteries, solar cells, as well as rechargeable batteries with recharging base.

With reference to FIG. 1, the microfluidic delivery system **10** may be powered by rechargeable batteries disposed within the interior **21** of the housing. The rechargeable batteries may be charged using a charger **38**. The charger **38** may include an power cord **39** that connects with an external power source, such as an electrical outlet or battery terminals. The charger **38** may receive the housing **12** to charge the batteries. As will be discussed in more detail below, electrical contacts **48** disposed on the interior **21** of the housing couple with the internal or external power source and couple with electrical contacts on the microfluidic delivery member of the cartridge to power the die. The housing **12** may include a power switch on exterior **23** of the housing **12**.

With reference to FIG. 5, the opening **20** may be disposed in the upper or body portion **14** or **18** of the housing **12**. The housing **12** may include a door **30** or structure to cover the opening **20**. The cartridge **26** may slide in through the opening in the body portion **18** of the housing **12**. The housing **12** may include air outlet **28** that places an environment on the exterior **23** of the housing **12** in fluid communication with the interior **21** of the housing **12**. The door **30** may rotate to provide access to the air outlet **28**. However, it is to be appreciated that the door or covering may be configured in various different ways. The door **30** may form a substantially air tight connection with the remainder of the housing **12** such that pressurized air in the interior **21** of the housing **12** does not escape through any gaps between the door **30** and the housing.

Cartridge

With reference to FIGS. 1 and 6-13, the cartridge **26** may have a longitudinal axis A and may comprise a reservoir **50** for containing a fluid composition **52**. The cartridge **26** may include a die **92** and a fluid transport member **80**. The fluid transport member **80** may be configured to deliver fluid composition from the reservoir **50** to the die **92**. The die **92** may be configured to dispense the fluid composition into the air or onto a target surface. The cartridge **26** may include an outer cover **40** that is mechanically connected with the reservoir **50**. The outer cover **40** may include an orifice **42** that at least partially exposes the die **92**. The orifice **42** may be adjacent to the die **92**, and may be at least partially aligned with the die **92**. An air flow path **46** may be formed in a gap between the reservoir **50** and the outer cover **40**. When the cartridge **26** is connected with the housing **12**, at least a portion of the outer cover **40** may be visible from the exterior of the housing **12**. Air pressure generated by the fan causes air to travel through the air flow path **46** and out of the orifice **42**. The fluid composition **52** dispensed from the die **92** combines with the air exiting the orifice **42**, helping the fluid composition **52** to be dispensed into the air and adequately fill a room or space.

air through the air flow path **46** as the die **92** dispenses a portion of fluid composition into the air, causing the fluid composition **52** to exit through the orifice **42** of the outer cover **40**. The air flow from the fan **32** provides additional force to carry the dispensed fluid composition **52** into the air, which, in turn, can increase room fill, and/or decrease deposition, and/or direct the fluid composition to the desired target. It is to be appreciated that increased air flow through the air flow path **46** is associated with increased carrying of the fluid composition **52** into the air. Moreover, the size of the orifice can be adjusted in order to control the velocity of the air flowing through the orifice **42**.

Reservoir

With reference to FIGS. 6-9, 11, and 12, the cartridge **26** includes a reservoir **50** for containing a fluid composition. The reservoir **50** may be configured to contain from about 5 milliliters (mL) to about 100 mL, alternatively from about 10 mL to about 50 mL, alternatively from about 15 mL to about 30 mL of fluid composition. The cartridge **26** may be configured to have multiple reservoirs, with each reservoir containing the same or a different fluid composition. The reservoir can be made of any suitable material for containing a fluid composition including glass, plastic, metal, or the like.

The reservoir **50** may be comprised of a top portion **51**, a base portion **53** opposing the top portion **51**, and at least one sidewall **61** connected with and extending between the top portion **51** and the base portion **53**. The reservoir **50** may define an interior **59** and an exterior **57**. The top portion **51** of the reservoir **50** may include an air vent **93** and a fluid outlet **90**. While the reservoir **50** is shown as having a top portion **51**, a base portion **53**, and at least one sidewall **61**, it is to be appreciated that the reservoir **50** may be configured in various different ways.

The reservoir **50**, including the top portion **51**, base portion **53**, and sidewall(s) **61**, may be configured as a single element or may be configured as separate elements that are joined together. For example, the top portion **51** or base portion **53** may be configured as a separate element from the remainder of the reservoir **50**. For example, with reference to FIGS. 7 and 8, the reservoir **50** may be comprised of two elements joined together; the base portion **53** and the sidewall(s) **61** may be one element and the top portion **51** may be a separate element. The top portion **51** may be configured as a lid **54** that is mechanically connected with the sidewall(s) **61**. The lid **54** may be removably or fixably connected with the sidewall(s) **61** to substantially enclose the reservoir **50**. The lid **54** may be threadingly attached with the sidewall(s) **61** of the reservoir **50**, or may be welded, glued, or the like with the sidewall(s) **61** of the reservoir **50**.

With reference to FIGS. 7-8 and 13, the reservoir **50** may include a connection member **86** extending from the interior **59** of the reservoir **50**. The connection member **86** may define a chamber **88** for receiving a portion of the second end portion **84** of the fluid transport member **80**. The chamber **88** may be substantially sealed between the connection member **86** and the fluid transport member **80** to prevent air from the reservoir **50** from entering the chamber **88**.

In an example configuration wherein the top portion **51** of the reservoir **50** includes a lid **54**, the connection member **86** may extend from the lid **54**. The lid **54** of the reservoir may be defined by an outer surface **58** and an inner surface **60**. The lid **54** may include a connection member **86** extending from the inner surface **60**.

The reservoir may be transparent, translucent, or opaque or any combination thereof. For example, the reservoir may be opaque with a transparent indicator of the level of fluid composition in the reservoir.

Fluid Transport Member

With reference to FIGS. 7 and 8, the cartridge **26** includes a fluid transport member **80** disposed within the interior **59** of the reservoir **50**. The fluid transport member **80** may be defined by a first end portion **82**, a second end portion **84**, and a central portion **83**. The first end portion **82** is in fluid communication with the fluid composition **52** in the reservoir **50** and the second end portion **84** is operatively connected with the connection member **86** of the reservoir **50**. The second end **84** of the fluid transport member **80** is located below the microfluidic delivery member **64**. The fluid transport member **80** delivers fluid composition from the reservoir **50** to the microfluidic delivery member **64**. Fluid composition can travel by wicking, diffusion, suction, siphon, vacuum, or other mechanism against the force of gravity. The fluid composition may be transported to the microfluidic delivery member **64** by a gravity fed system known in the art.

The fluid transport member **80** may be configured in various ways, including in the form of a capillary tube or wicking material. The wicking material may be in the form of a metal or fabric mesh, sponge, or fibrous or porous wick that contains multiple interconnected open cells that form capillary passages to draw a fluid composition up from the reservoir to the microfluidic delivery member. Non-limiting examples of suitable compositions for the fluid transport member include polyethylene, ultra-high molecular weight polyethylene, nylon 6, polypropylene, polyester fibers, ethyl vinyl acetate, polyether sulfone, polyvinylidene fluoride, and polyethersulfone, polytetrafluoroethylene, and combinations thereof. Many traditional ink jet cartridges use an open-cell polyurethane foam which can be incompatible with perfume mixtures over time (e.g. after 2 or 3 months) and can break down. The fluid transport member **80** may be free of a polyurethane foam.

The fluid transport member **80** may be a high density wick composition to aid in containing the scent of a perfume mixture. The fluid transport member may be made from a plastic material chosen from high-density polyethylene or polyester fiber. As used herein, high density wick compositions include any conventional wick material having a pore radius or equivalent pore radius (e.g. in the case of fiber based wicks) ranging from about 20 microns to about 200 microns, alternatively from

Regardless of the material of manufacture, where a wicking material is used, the fluid transport member **80** can exhibit an average pore size from about 10 microns to about 500 microns, alternatively from about 50 microns to about 150 microns, alternatively about 70 microns. The average pore volume of the wick, expressed as a fraction of the fluid transport member not occupied by the structural composition, is from about 15% to about 85%, alternatively from about 25% to about 50%. Good results have been obtained with wicks having an average pore volume of about 38%.

The fluid transport member **80** may be any shape that is able to deliver fluid composition from the reservoir **50** to the microfluidic delivery member **64**. Although the fluid transport member **80** has a width dimension, such as diameter, that is significantly smaller than the reservoir **50**, it is to be appreciated that the diameter of the fluid transport member **80** may be larger and may substantially fill the reservoir **50**. The fluid transport member **80** can also be of variable length, such as, from about 1 mm to about 100 mm, or from about 5 mm to about 75 mm, or from about 10 mm to about 50 mm.

With reference to FIG. 8, if the fluid transport member **80** is configured as a capillary tube, the fluid transport member **80** may include a restriction member **81**. The restriction member **81** prevents or minimizes the chance of an air bubble from the reservoir **50** passing through the fluid transport member **80** and blocking the nozzles **130** of the die **92**. An exemplary restriction member is described in U.S. Patent Application entitled, "MICROFLUIDIC DELIVERY SYSTEM AND CARTRIDGE", Ser. No. 14/855,677, filed on Sep. 16, 2015.

Microfluidic Delivery Member

With reference to FIGS. 7-10 and 14A-15B, the microfluidic delivery system **10** may comprise a microfluidic delivery member **64** that utilizes aspects of ink-jet print head systems, and more particularly, aspects of thermal or piezo ink-jet print heads. The microfluidic delivery member **64** may be connected with the top portion **51** and/or sidewall **61** of the reservoir **50** of the cartridge **26**.

In a "drop-on-demand" ink-jet printing process, a fluid composition is ejected through a very small orifice of a diameter typically about 5-50 microns, or between about 10 and about 40 microns, in the form of minute droplets by rapid pressure impulses. The rapid pressure impulses are typically generated in the print head by either expansion of a piezoelectric crystal vibrating at a high frequency or volatilization of a volatile composition (e.g. solvent, water, propellant) within the ink by rapid heating cycles. Thermal ink-jet printers employ a heating element within the print head to volatilize a portion of the composition that propels a second portion of fluid composition through the orifice nozzle to form droplets in proportion to the number of on/off cycles for the heating element. The fluid composition is forced out of the nozzle when needed. Conventional ink-jet printers are more particularly described in U.S. Pat. Nos. 3,465,350 and 3,465,351.

The microfluidic delivery member **64** may be in electrical communication with a power source and may include a printed circuit board ("PCB") **106** and a die **92** that is in fluid communication with the fluid transport member **80**.

The PCB **106** may be a rigid planar circuit board, such as shown in FIGS. 14A and 14B for illustrative purposes only; a flexible PCB; or a semi-flex PCB, such as shown in FIGS. 15A and 15B for illustrative purposes only. The semi-flex PCB shown in FIGS. 15A and 15B may include a fiberglass-epoxy composite that is partially milled in a portion that allows a portion of the PCB **106** to bend. The milled portion may be milled to a thickness of about 0.2 millimeters. The PCB **106** has upper and lower surfaces **68** and **70**.

The PCB **106** may be of a conventional construction. It may comprise a ceramic substrate. It may comprise a fiberglass-epoxy composite substrate material and layers of conductive metal, normally copper, on the top and bottom surfaces. The conductive layers are arranged into conductive paths through an etching process. The conductive paths are protected from mechanical damage and other environmental effects in most areas of the board by a photo-curable polymer layer, often referred to as a soldermask layer. In selected areas, such as the liquid flow paths and wire bond attachment pads, the conductive copper paths are protected by an inert metal layer such as gold. Other material choices could be tin, silver, or other low reactivity, high conductivity metals.

Still referring to FIGS. 14A-16, the PCB **106** may include all electrical connections—the contacts **74**, the traces **75**, and the contact pads **112**. The contacts **74** and contact pads **112** may be disposed on the same side of the PCB **106**, or may be disposed on different sides of the PCB. For example, as shown in FIGS. 14A and 14B, the contacts **74** may be disposed on opposite sides of the PCB **106**. The contacts **74** may be disposed on the lower surface **70** of the PCB **106** and the contact pads **112** may be disposed on the upper surface **68** of the PCB **106**. With reference to FIGS. 15A and 15B, the contacts **74** may be disposed on the same side as the contact pads **112**. For example, the contacts **74** and the contact pads **112** may be disposed on the upper surface **68**.

With reference to FIGS. 14A and 14B, the die **92** and the contacts **74** may be disposed on parallel planes. This allows for a simple, rigid PCB **106** construction. The contacts **74** and the die **92** may be disposed on the same side of the PCB **106** or may be disposed on opposite sides of the PCB **106**.

The PCB **106** includes the electrical contacts **74** at the first end and contact pads **112** at the second end proximate the die **92**. With reference to FIG. 15A, electrical traces **75** from the contact pads **112** to the electrical contacts are formed on the board and may be covered by the solder mask or another dielectric. Electrical connections from the die **92** to the PCB **106**

116, normally an epoxy compound, is applied to the wire bond area to protect the delicate connections from mechanical damage and other environmental effects.

With reference to FIGS. 13, 14B, and 16, the microfluidic delivery member **64** may include a filter **96**. The filter **96** may be disposed on the lower surface **70** of the PCB **106**. The filter **96** may separate the opening **78** of the board from the chamber **88** at the lower surface of the board. The filter **96** may be configured to prevent at least some of particulates from passing through the opening **78** to prevent clogging the nozzles **130** of the die **92**. The filter **96** may be configured to block particulates that are greater than one third of the diameter of the nozzles **130**. It is to be appreciated that the fluid transport member **80** can act as a suitable filter **96**, so that a separate filter is not needed. The filter **96** may be a stainless steel mesh. The filter **96** may be randomly weaved mesh, polypropylene or silicon based.

With reference to FIGS. 13-16, the filter **96** may be attached to the bottom surface with an adhesive material that is not readily degraded by the fluid composition in the reservoir **50**. The adhesive may be thermally or ultraviolet activated. The filter **96** is positioned between the chamber **88** and the die **92**. The filter **96** is separated from the bottom surface of the microfluidic delivery member **64** by a mechanical spacer **98**. The mechanical spacer **98** creates a gap **99** between the bottom surface **70** of the microfluidic delivery member **64** and the filter **96** proximate the opening **78**. The mechanical spacer **98** may be a rigid support or an adhesive that conforms to a shape between the filter **96** and the microfluidic delivery member **64**. In that regard, the outlet of the filter **96** is greater than the diameter of the opening **78** and is offset therefrom so that a greater surface area of the filter **96** can filter fluid composition than would be provided if the filter was attached directly to the bottom surface **70** of the microfluidic delivery member **64** without the mechanical spacer **98**. It is to be appreciated that the mechanical spacer **98** allows suitable flow rates through the filter **96**. That is, as the filter **96** accumulates particles, the filter will not slow down the fluid flowing therethrough. The outlet of the filter **96** may be about 4 mm² or larger and the standoff is about 700 microns thick.

The opening **78** may be formed as an oval, as is illustrated in FIG. 16; however, other shapes are contemplated depending on the application. The oval may have the dimensions of a first diameter of about 1.5 mm and a second diameter of about 700 microns. The opening **78** exposes sidewalls **102** of the PCB **106**. If the PCB **106** is an FR4 PCB, the bundles of fibers would be exposed by the opening. These sidewalls are susceptible to fluid composition and thus a liner **100** is included to cover and protect these sidewalls. If fluid composition enters the sidewalls, the PCB **106** could begin to deteriorate, cutting short the life span of this product.

The PCB **106** may carry a die **92**. The die **92** comprises a fluid injection system made by using a semiconductor micro fabrication process such as thin-film deposition, passivation, etching, spinning, sputtering, masking, epitaxy growth, wafer/wafer bonding, micro thin-film lamination, curing, dicing, etc. These processes are known in the art to make MEMS devices. The die **92** may be made from silicon, glass, or a mixture thereof. The die **92** comprises a plurality of microfluidic chambers **128**, each comprising a corresponding actuation element: heating element or electromechanical actuator. In this way, the die's fluid injection system may be micro thermal nucleation (e.g. heating element) or micro mechanical actuation (e.g. thin-film piezoelectric). One type of die for the microfluidic delivery member is an integrated membrane of nozzles obtained via MEMS technology as described in U.S. 2010/0154790, assigned to STMicroelectronics S.R.L., Geneva, Switzerland. In the case of a thin-film piezo, the piezoelectric material (e.g. lead zirconium titanate) is typically applied via spinning and/or sputtering processes. The semiconductor micro fabrication process allows one to simultaneously make one or thousands of MEMS devices in one batch process (a batch process comprises of multiple mask layers).

The die **92** may be secured to the upper surface **68** of the PCB **106** above the opening **78**. The die **92** may be secured to the upper surface of the PCB **106** by any adhesive material configured to hold the semiconductor die to the board. The adhesive material may be the same or different from the adhesive material used to secure the filter **96** to the microfluidic delivery member **64**.

The die **92** may comprise a silicon substrate, conductive layers, and polymer layers. The silicon substrate forms the supporting structure for the other layers, and contains a channel for delivering fluid composition from the bottom of the die to the upper layers. The conductive layers are deposited on the silicon substrate, forming electrical traces with high conductivity and heaters with lower conductivity. The polymer layers form passages, firing chambers, and nozzles **130** which define the drop formation geometry.

FIGS. 16-20 include more details of the die **92**. The die **92** includes a substrate **107**, a plurality of intermediate layers **109**, and a nozzle plate **132**. The nozzle plate **132** includes an outer surface **133** that subtends a surface area. The plurality of intermediate layers **109** include dielectric layers and a chamber layer **148** that are positioned between the substrate and the nozzle plate **132**. The nozzle plate **132** may be about 12 microns thick.

The die **92** includes a plurality of electrical connection leads **110** that extend from one of the intermediate layers **109** down to the contact pads **112** on the circuit PCB **106**. At least one lead couples to a single contact pad **112**. Openings **150** on the left and right side of the die **92** provide access to the intermediate layers **109** to which the leads **110** are coupled. The openings **150** pass through the nozzle plate **132** and chamber layer **148** to expose contact pads **152** that are formed on the intermediate dielectric layers. There may be one opening **150** positioned on only one side of the die **92** such that all of the leads that extend from the die extend from one side while other side remains unencumbered by the leads.

purposes only, there are eighteen nozzles **130** shown through the nozzle plate **132**, nine nozzles on each side of a center line. Each nozzle **130** may deliver about 0.5 to about 20 picoliters, or about 1 to about 10 picoliters, or about 2 to about 6 picoliters of a fluid composition per electrical firing pulse. The volume of fluid composition delivered from each nozzle per electrical firing pulse may be analyzed using image-based drop analysis where strobe illumination is coordinated in time with the production of drops, one example of which is the JetXpert system, available from ImageXpert, Inc. of Nashua, N.H., with the droplets measured at a distance of 1-3 mm from the top of the die. The nozzles **130** may be positioned about 60 μm to about 110 μm apart. Twenty nozzles **130** may be present in a 3 mm² area. The nozzles **130** may have a diameter of about 5 μm to about 40 μm , or 10 μm to about 30 μm , or about 20 μm to about 30 μm , or about 13 μm to about 25 μm . FIG. 18 is a top down isometric view of the die **92** with the nozzle plate **132** removed, such that the chamber layer **148** is exposed.

Generally, the nozzles **130** are positioned along a fluidic feed channel through the die **92** as shown in FIGS. 20 and 21. The nozzles **130** may include tapered sidewalls such that an upper opening is smaller than a lower opening. The heater may be square, having sides with a length. In one example, the upper diameter is about 13 μm to about 18 μm and the lower diameter is about 15 μm to about 20 μm . At 13 μm for the upper diameter and 18 μm for the lower diameter, this would provide an upper area of 132.67 μm^2 and a lower area of 176.63 μm^2 . The ratio of the lower diameter to the upper diameter would be around 1.3 to 1. In addition, the area of the heater to an area of the upper opening would be high, such as greater than 5 to 1 or greater than 14 to 1.

Each nozzle **130** is in fluid communication with the fluid composition in the reservoir **50** by a fluid path. Referring to FIG. 13 and FIGS. 20 and 21, the fluid path from the reservoir **50** includes the first end **82** of the fluid transport member **80**, through the transport member to the second end **84** of the transport member, through the chamber **88**, through the first through-hole **90**, through the opening **78** of the PCB **106**, through an inlet **94** of the die **92**, then through a channel **126**, and then through the chamber **128**, and out of the nozzle **130** of the die.

Proximate each nozzle chamber **128** is a heating element **134** (see FIGS. 19 and 22) that is electrically coupled to and activated by an electrical signal being provided by one of the contact pads **152** of the die **92**. Referring to FIG. 19, each heating element **134** is coupled to a first contact **154** and a second contact **156**. The first contact **154** is coupled to a respective one of the contact pads **152** on the die by a conductive trace **155**. The second contact **156** is coupled to a ground line **158** that is shared with each of the second contacts **156** on one side of the die. There may be only a single ground line that is shared by contacts on both sides of the die. Although FIG. 19 is illustrated as though all of the features are on a single layer, they may be formed on several stacked layers of dielectric and conductive material. Further, while the illustrated embodiment shows a heating element **134** as the activation element, the die **92** may comprise piezoelectric actuators in each chamber **128** to dispense the fluid composition from the die.

In use, when the fluid composition in each of the chambers **128** is heated by the heating element **134**, the fluid composition vaporizes to create a bubble. The expansion that creates the bubble causes fluid composition to eject from the nozzle **130** and to form a plume of one or more droplets.

With reference to FIGS. 17 and 18, the substrate **107** includes an inlet path **94** coupled to a channel **126** that is in fluid communication with individual chambers **128**, forming part of the fluid path. Above the chambers **128** is the nozzle plate **132** that includes the plurality of nozzles **130**. Each nozzle **130** is above a respective one of the chambers **128**. The die **92** may have any number of chambers and nozzles, including one chamber and nozzle. For illustrative purposes only, the die is shown as including eighteen chambers each associated with a respective nozzle. Alternatively, it can have ten nozzles and two chambers provided fluid composition for a group of five nozzles. It is not necessary to have a one-to-one correspondence between the chambers and nozzles.

As best seen in FIG. 18, the chamber layer **148** defines angled funnel paths **160** that feed the fluid composition from the channel **126** into the chamber **128**. The chamber layer **148** is positioned on top of the intermediate layers **109**. The chamber layer defines the boundaries of the channels and the plurality of chambers **128** associated with each nozzle **130**. The chamber layer may be formed separately in a mold and then attached to the substrate. The chamber layer may be formed by depositing, masking, and etching layers on top of the substrate.

The intermediate layers **109** include a first dielectric layer **162** and a second dielectric layer **164**. The first and second dielectric layers are between the nozzle plate and the substrate. The first dielectric layer **162** covers the plurality of first and second contacts **154**, **156** formed on the substrate and covers the heaters **134** associated with each chamber. The second dielectric layer **164** covers the conductive traces **155**.

With reference to FIG. 19, the first and second contacts **154**, **156** are formed on the substrate **107**. The heaters **134** are formed to overlap with the first and second contacts **154**, **156** of a respective heater assembly. The contacts **154**, **156** may be formed of a first metal layer or other conductive material. The heaters **134** may be formed of a second metal layer or other conductive material. The heaters **134** are thin-film resistors that laterally connect the first and second contacts **154**, **156**. Instead of being formed directly on a top surface of the contacts, the heaters **134** may be coupled to the contacts **154**, **156** through vias or may be formed below the contacts.

The heater **134** may be a piezoelectric thin-film actuator structure layer. The heater **134** may include obstructive pillars.

the heaters **134** may include tantalum silicon nitride and tungsten silicon nitride. The heaters **134** may also include a 30-nanometer cap of silicon nitride. The heaters **134** may be formed by depositing multiple thin-film layers in succession. A stack of thin-film layers combine the elementary properties of the individual layers.

A ratio of an area of the heater **134** to an area of the nozzle **130** may be greater than seven to one. The heater **134** may be square, with each side having a length **147**. The length may be 47 microns, 51 microns, or 71 microns. This would have an area of 2209, 2601, or 5041 microns square, respectively. If the nozzle diameter is 20 microns, an area at the second end would be 314 microns square, giving an approximate ratio of 7 to 1, 8 to 1, or 16 to 1, respectively.

With reference to FIG. 23, a length of the first contact **154** can be seen adjacent to the inlet **94**. A via **151** couples the first contact **154** to trace **155** that is formed on the first dielectric layer **162**. The second dielectric layer **164** is on the trace **155**. A via **149** is formed through the second dielectric layer **164** and couples the trace **155** to the contact pad **152**. A portion of the ground line **158** is visible toward an edge **163** of the die, between the via **149** and the edge **163**.

As can be seen in this cross-section, the die **92** may be relatively simple and free of complex integrated circuitry. This die **92** will be controlled and driven by an external microcontroller or microprocessor. The external microcontroller or microprocessor may be provided in the housing. This allows the PCB **106** and the die **92** to be simplified and cost effective. There may be two metal or conductive levels formed on the substrate. These conductive levels include the contact **154** and the trace **155**. All of these features can be formed on a single metal level. This allows the die to be simple to manufacture and minimizes the number of layers of dielectric between the heater and the chamber.

Referring now to FIG. 24, there is provided a close-up view of a portion of a microfluidic cartridge **26** illustrating a flow path with a filter **96** between the second end **84** of the fluid transport member **80** and the die **92**. The opening **78** of the microfluidic delivery member **64** may include a liner **100** that covers exposed sidewalls **102** of the PCB **106**. The liner **100** may be any material configured to protect the PCB **106** from degradation due to the presence of the fluid composition, such as to prevent fibers of the board from separating. In that regard, the liner **100** may protect against particles from the PCB **106** entering into the fluid path and blocking the nozzles **130**. For instance, the opening **78** may be lined with a material that is less reactive to the fluid composition in the reservoir than the material of the PCB **106**. In that regard, the PCB **106** may be protected as the fluid composition passes therethrough. The through hole may be coated with a metal material, such as gold.

Outer Cover

With reference to FIGS. 6-10, the cartridge **26** includes an outer cover **40**. The outer cover **40** may be defined by an interior **49** and an exterior **63**. The outer cover **40** may include a top **41** that is defined by a perimeter **43**. The top **41** of the outer cover **40** may be defined by a surface area that is bounded by the perimeter **43**. The top **41** includes an orifice **42**. The top **41** of the outer cover **40** may substantially cover the top portion **51** of the reservoir **50**. The orifice **42** may be disposed adjacent to the die **92**. The orifice **42** may be at least partially aligned with the die **92**. The orifice **42** may expose the die **92** to the exterior **23** of the housing **12**.

The outer cover **40** is connected with the reservoir **50** such that a gap is formed between the outer cover **40** and the reservoir **50**, forming an air flow path **46** between the outer cover **40** and the reservoir **50**. The air flow path **46** allows air from the fan **32** to force the fluid composition **52** dispensed from the microfluidic delivery member **64** out of the orifice **42** and into the room or space. Restricting the air flow and the dispensed fluid composition **52** to flow through the orifice **42** can increase the velocity of the fluid composition **52** dispensed from the cartridge **26**. Generally, the greater the velocity of the fluid composition **52** dispensed from the cartridge **26**, the greater the distance the fluid composition **52** will be able to travel into the air; thus, the velocity of the fluid composition **52** can positively impact the dispersion of the fluid composition **52** into a room or space. The size of the orifice **42** can directly impact the velocity of the fluid composition **52** due to the air velocity of the air from the fan.

The outer cover **40** may include a skirt **45** that extends from the perimeter **43** of the top **41** toward the reservoir **50**. The skirt **45** may surround at least a portion of the sidewall(s) **61** of the reservoir **50**. The skirt **45** may be configured such that air is able to flow longitudinally adjacent to the sidewall(s) **61** of the reservoir **50**. Air may flow longitudinally through the air flow path. Moreover, directing the air flow from the fan **32** through the air flow path **46** allows for a uniform flow of air from the skirt **45** to the orifice **42**, minimizing the opportunity for turbulence to form inside of the outer cover **40** that could cause dispensed fluid composition **52** to become trapped in the air flow path **46** and possibly redeposited onto the die **92**.

The outer cover **40**, including the top **41** and/or the skirt **45**, may cover at least a portion of the microfluidic delivery member **64**. The outer cover **40** may cover the entire microfluidic delivery member **64**. With reference to FIGS. 8 and 9, with a semi-flex PCB **106**, the top **41** of the outer cover **40** may cover a portion of the PCB **106** and the skirt **45** may cover a portion of the PCB **106** because the PCB **106** extends from the top portion **51** to the sidewall(s) **61** of the reservoir **50**. With reference to FIG. 10, in a cartridge comprising a rigid PCB **106**, the top **41** of the outer cover **40** may cover substantially all of the PCB **106**. In such an exemplary configuration, the outer cover **40** may or may not include a skirt **45**. Covering the electrical contacts **74** and the die **92** of the microfluidic delivery member **64** can prevent damage that may be caused by a user touching the electrical contacts **74** and/or die **92**. For example, oil and/or dirt on a user's hands can clog the die **92** and prevent fluid composition from exiting through the nozzles **130** of the die **92**. Also, oil and dirt can

electrical contacts **74** on the microfluidic delivery member **64** and the electrical contacts **48** on the housing **12**.

Moreover, the skirt **45** of the outer cover **40** provides a safe and/or ergonomic surface for a user to grasp as the user inserts and removes the cartridge **26** from the housing **12** without damaging the microfluidic delivery member **64**. The outer cover **40** can also improve the aesthetic appearance of the cartridge **26** by covering the microfluidic delivery member **64**.

The orifice **42** may expose at least a portion of, or substantially all of, or all of, the die **92**. By exposing at least a portion of the die **92**, the fluid composition dispensed from the die **92** is unrestricted as it passes through the orifice **42**. As a result, deposition of fluid composition onto the outer cover **40** after it is dispensed from the die **92** may be kept to a minimum or even prevented.

The outer cover **40** may be configured such that air flow through the air flow path **46** increases in pressure from the skirt **45** to the orifice **42**. The air flow path **46** may continually increase in pressure from the skirt **45** to the orifice **42**. It is to be appreciated that if the pressure through the air flow path **46** is increased and then decreased before the air exits the orifice **42**, eddies may be formed that reduce the air flow out of the orifice **42** or cause fluid composition **52** to become trapped in the air flow path **46** or on the top portion **51** of the reservoir **50**.

The orifice **42** may be defined by a perimeter **65** and a surface area that is bounded by the perimeter **65** of the orifice **42**. The surface area of the orifice **42** may be greater than the surface area of the nozzle plate **132**. The surface area of the orifice **42** may be at least 10%, or at least 20%, or at least 30% greater than the surface area of the nozzle plate **132**. The orifice **42** may have a surface area of about 40 mm² to about 200 mm², or about 75 mm² to about 150 mm². The surface area of the orifice **42** may be at least 5%, or at least 10%, or at least 15%, or at least 20% of the surface area of the top **41**. It is to be appreciated that the surface area of the orifice **42** can impact the velocity of fluid composition and air flow exiting the orifice **42**; a smaller surface area of the orifice may result in a lower velocity of air flow and fluid composition exiting the orifice **42**.

The perimeter **65** of the orifice **42** may be configured in various different shapes. For example, the orifice **42** may have a circular, arcuate, square, rectangular, star, polygon, or various other shapes. The orifice **42** may be concentric or eccentric with the top **41** of the outer cover **40**. The orifice **42** may be congruent with the top **41** of the outer cover **42**.

The outer cover **40** may be connected with the reservoir **50** in various ways, including permanently or releasably. For example, the outer cover **40** may be welded, glued, friction-fitted, or the like, to the reservoir **50**. One or more connection elements **47** of the outer cover **40** may mate with one or more connection elements **62** on the reservoir **50**, or one or more connection elements **47** of the outer cover **40** may mate with the reservoir **50**. The connection elements **47** on the outer cover may be welded or glued to the connection elements **62** on the reservoir **50** to permanently fix the outer cover **40** to the reservoir **50**. Permanently or temporarily fixing the outer cover **40** to the reservoir **50** prevents the outer cover **40** from moving relative to the reservoir **50** as air from the fan **32** flows through the air flow path **46** between the outer cover **40** and the reservoir **50**. The location of the connection elements **47** on the outer cover **40** may be the only location where a gap does not exist between the outer cover **40** and the reservoir **50**. As such, the connection elements **47** on the outer cover **47** and the connection elements **62** on the reservoir **50** may be relatively small in order to allow the air to flow toward the orifice **42** of the outer cover **40**.

The outer cover **40** may have various shapes. For example, the top **41** of the outer cover **40** may be flat, substantially flat, curved, waved, or the like. The shape of the top **41** of the outer cover **40** may be symmetrical, asymmetrical, regular, or irregular. The exterior **63** of the outer cover **40** may have various textures, including smooth, bumpy, wavy, or the like. The top **41** of the outer cover **40** may have the same surface texture as the skirt **45** of the outer cover **40**, or may have a different surface texture than the skirt **45**. The skirt **45** of the outer cover **40** may have a texture or indentation(s) for a user to grip as the user is inserting or removing the cartridge **26** from the housing **10**.

The outer cover **40** may have various dimensions. For example, the skirt **45** of the outer cover **40** may be defined by a length L extending from the perimeter **43** of the top **41** of the outer cover **40** that extends down toward the base portion **53** of the reservoir **50**. For example, the length L may be in the range of about 5 millimeters to about 25 millimeters, or about 10 millimeters to about 20 millimeters. The skirt **45** of the outer cover **40** may cover a portion of the sidewall(s) **61** of the reservoir **50**. For example, the skirt **45** of the outer cover **40** may cover at least 10% or at least 20% or at least 30% of the surface area of the sidewall(s) **61** of the reservoir **50**. The outer cover **40** may be appropriately sized in order to form the desired air flow path **46** dimensions formed in the gap between the outer cover **40** and the reservoir **50**. The thickness of the outer cover **40**, including the skirt **45** and the top **41**, may have various dimensions, depending upon the desired strength and durability and on the material of the outer cover **40**. The thickness of the outer cover **40** may be uniform or non-uniform.

With reference to FIG. 11, the air flow path **46** may be defined by a width W extending between the reservoir **50** and the outer cover **40**. The width W may be at least 2 millimeters, or at least 2.5 millimeters, or at least 3 millimeters. The width W of the air flow path **46** may be in the range of about 2 millimeters to about 5 millimeters. The width W of the air flow path **46** may be uniform or may vary because of the non-uniform surface and various structural components of the reservoir **50**.

The outer cover **40** may be comprised of various materials. For example, the outer cover **40** may be comprised of a rigid polymeric material, such as Copolyester TRITAN® from Eastman, Polypropylene, Nylon, PBT, or other perfume or solvent resistant plastics. The outer cover **40** may be the same material as the reservoir **50** or a different material than the reservoir **50**. The outer cover **40** may be the same color as the reservoir **50** or may be a different color than the reservoir **50**. The outer cover **40** may be transparent or opaque so that the microfluidic delivery member **64** is less visible or not visible from the exterior **63** of the outer cover **40**.

In a configuration having a lid **54** form a portion of the reservoir **50**, the outer cover **40** may surround at least a portion of the lid **54**. The outer cover **40** may cover the entire lid **54**.

The outer cover **40** may include a screen that overlaps with the orifice **42** of the outer cover **40**. The screen may prevent a user from accessing the microfluidic delivery member **64**.

Sensors

The delivery system may include commercially available sensors that respond to environmental stimuli such as light, noise, motion, and/or odor levels in the air. For example, the delivery system can be programmed to turn on when it senses light, and/or to turn off when it senses no light. In another example, the delivery system can turn on when the sensor senses a person moving into the vicinity of the sensor. Sensors may also be used to monitor the odor levels in the air. The odor sensor can be used to turn-on the delivery system, increase the heat or fan speed, and/or step-up the delivery of the fluid composition from the delivery system when it is needed.

VOC sensors can be used to measure intensity of perfume from adjacent or remote devices and alter the operational conditions to work synergistically with other perfume devices. For example a remote sensor could detect distance from the emitting device as well as fragrance intensity and then provide feedback to device on where to locate device to maximize room fill and/or provide the "desired" intensity in the room for the user.

The devices may communicate with each other and coordinate operations in order to work synergistically with other perfume devices.

The sensor may also be used to measure fluid composition levels in the reservoir or count firing of the heating elements to indicate the cartridge's end-of-life in advance of depletion. In such case, an LED light may turn on to indicate the reservoir needs to be filled or replaced with a new reservoir.

The sensors may be integral with the delivery system housing or in a remote location (i.e. physically separated from the delivery system housing) such as remote computer or mobile smart device/phone. The sensors may communicate with the delivery system remotely via low energy blue tooth, 6 low pan radios or any other means of wirelessly communicating with a device and/or a controller (e.g. smart phone or computer).

The user may be able to change the operational condition of the device remotely via low energy blue tooth, or other means.

Smart Chip

The cartridge **26** may include a memory in order to transmit optimal operational condition to the device.

Fluid Composition

To operate satisfactorily in a microfluidic delivery system, many characteristics of a fluid composition are taken into consideration. Some factors include formulating fluid compositions with viscosities that are optimal to emit from the microfluidic delivery member, formulating fluid compositions with limited amounts or no suspended solids that would clog the microfluidic delivery member, formulating fluid compositions to be sufficiently stable to not dry and clog the microfluidic delivery member, etc. Operating satisfactorily in a microfluidic delivery system, however, addresses only some of the requirements necessary for a fluid composition having more than 50 wt. % of a perfume mixture to atomize properly from a microfluidic delivery member and to be delivered effectively as an air freshening or malodor reducing composition.

The fluid composition may exhibit a viscosity of less than 20 centipoise ("cps"), alternatively less than 18 cps, alternatively less than 16 cps, alternatively from about 5 cps to about 16 cps, alternatively about 8 cps to about 15 cps. And, the volatile composition may have surface tensions below about 35, alternatively from about 20 to about 30 dynes per centimeter. Viscosity is in cps, as determined using the Bohlin CVO Rheometer system in conjunction with a high sensitivity double gap geometry.

The fluid composition is free of suspended solids or solid particles existing in a mixture wherein particulate matter is dispersed within a liquid matrix. Free of suspended solids is distinguishable from dissolved solids that are characteristic of some perfume materials.

The fluid composition may comprise volatile materials. Exemplary volatile materials include perfume materials, volatile dyes, materials that function as insecticides, essential oils or materials that acts to condition, modify, or otherwise modify

compositions (e.g. odor neutralizing materials such as reactive aldehydes (as disclosed in U.S. 2005/0124512), odor blocking materials, odor masking materials, or sensory modifying materials such as ionones (also disclosed in U.S. 2005/0124512)).

The volatile materials may be present in an amount greater than about 50%, alternatively greater than about 60%, alternatively greater than about 70%, alternatively greater than about 75%, alternatively greater than about 80%, alternatively from about 50% to about 100%, alternatively from about 60% to about 100%, alternatively from about 70% to about 100%, alternatively from about 80% to about 100%, alternatively from about 90% to about 100%, by weight of the fluid composition.

The fluid composition may contain one or more volatile materials selected by the material's boiling point ("B.P."). The B.P. referred to herein is measured under normal standard pressure of 760 mm Hg. The B.P. of many perfume ingredients, at standard 760 mm Hg can be found in "Perfume and Flavor Chemicals (Aroma Chemicals)," written and published by Steffen Arctander, 1969.

The fluid composition may include a perfume mixture of one or more perfume materials. The perfume mixture may have an average boiling point of less than 275° C., alternatively less than 250° C., alternatively less than 220° C., alternatively less than about 180° C., alternatively about 70° C. to about 250° C. A quantity of low B.P. ingredients (<200° C.) in the perfume mixture can be used to help higher boiling point formulations to be ejected. A fluid composition with a boiling point above 250° C. could be made to eject with good performance if the fluid composition comprises from about 50% to about 100%, or about 60% to about 100%, or about 75% to about 100%, by weight of the fluid composition, of a perfume mixture of volatile perfume materials, wherein the perfume mixture has an average boiling point of less than 250° C., or less than 225° C. despite the overall average of the fluid composition still being above 250° C.

The fluid composition may comprise, consist essentially of, or consist of volatile perfume materials.

Tables 2 and 3 outline technical data on perfume materials suitable for the present fluid composition 52. Approximately 10%, by weight of the fluid composition, may be ethanol, which may be used as a diluent to reduce boiling point to a level less than 250° C. Flash point may be considered in choosing the perfume formulation as flash points less than 70° C. require special shipping and handling in some countries due to flammability. Hence, there may be advantages to formulate to higher flash points.

Table 2 lists some non-limiting, exemplary individual perfume materials suitable for the present fluid composition.

TABLE 2

CAS Number Perfume Raw Material Name B.P. (° C.)

105-37-3	Ethyl propionate	99
110-19-0	Isobutyl acetate	116
928-96-1	Beta gamma hexenol	157
80-56-8	Alpha Pinene	157
127-91-3	Beta Pinene	166
1708-82-3	cis-hexenyl acetate	169
124-13-0	Octanal	170
470-82-6	Eucalyptol	175
141-78-6	Ethyl acetate	77

Table 3 shows an exemplary perfume mixture having a total B.P. less than 200° C.

TABLE 3

CAS Number Perfume Raw Material Name Wt % B.P. (° C.)

123-68-2	Allyl Caproate	2.50	185
140-11-4	Benzyl Acetate	3.00	214
928-96-1	Beta Gamma Hexenol	9.00	157
18479-58-8	Dihydro Myrcenol	5.00	198
39255-32-8	Ethyl 2 Methyl Pentanoate	9.00	157
77-83-8	Ethyl Methyl Phenyl Glycidate	2.00	260
7452-79-1	Ethyl-2-Methyl Butyrate	8.00	132
142-92-7	Hexyl Acetate	12.50	146
68514-75-0	Orange Phase Oil 25X1.18%- Low Cit. 14638	10.00	177

TABLE 3

CAS Number	Perfume Raw Material Name	Wt %	B.P. (° C.)
104-93-8	Para Cresyl Methyl Ether	0.20	176
1191-16-8	Prenyl Acetate	8.00	145
88-41-5	Verdax	3.00	223
58430-94-7	Iso Nonyl Acetate	27.30	225
	TOTAL:	100.00	

The fluid composition may also include solvents, diluents, extenders, fixatives, thickeners, or the like. Non-limiting examples of these materials are ethyl alcohol, carbitol, diethylene glycol, dipropylene glycol, diethyl phthalate, triethyl citrate, isopropyl myristate, ethyl cellulose, and benzyl benzoate.

The fluid composition may contain functional perfume components ("FPCs"). FPCs are a class of perfume raw materials with evaporation properties that are similar to traditional organic solvents or volatile organic compounds ("VOCs"). "VOCs", as used herein, means volatile organic compounds that have a vapor pressure of greater than 0.2 mm Hg measured at 20° C. and aid in perfume evaporation. Exemplary VOCs include the following organic solvents: dipropylene glycol methyl ether ("DPM"), 3-methoxy-3-methyl-1-butanol ("MMB"), volatile silicone oil, and dipropylene glycol esters of methyl, ethyl, propyl, butyl, ethylene glycol methyl ether, ethylene glycol ethyl ether, diethylene glycol methyl ether, diethylene glycol ethyl ether, or any VOC under the tradename of Dowanol™ glycol ether. VOCs are commonly used at levels greater than 20% in a fluid composition to aid in perfume evaporation.

The FPCs of the present fluid composition aid in the evaporation of perfume materials and may provide a hedonic, fragrance benefit. FPCs may be used in relatively large concentrations without negatively impacting perfume character of the overall composition. As such, The fluid composition may be substantially free of VOCs, meaning it has no more than 18%, alternatively no more than 6%, alternatively no more than 5%, alternatively no more than 1%, alternatively no more than 0.5%, by weight of the composition, of VOCs. The volatile composition may be free of VOCs.

Perfume materials that are suitable as FPCs are disclosed in U.S. Pat. No. 8,338,346.

Method of Operation

With reference to FIGS. 2-4 and 6-8, the microfluidic delivery system **10** may deliver a fluid composition **52** from the cartridge **26** using thermal heating or vibration via piezoelectric crystals, for example. The fluid transport member **80** directs fluid composition **52** contained within the reservoir **50** toward the die **92** of the microfluidic delivery member **64**. The fluid transport member **80** may be configured to direct the fluid composition **52** up, opposite the force of gravity to the die **92**. After passing through the second end portion **84** of the fluid transport member **80**, the fluid composition **52** travels through the die **92**.

In a microfluidic delivery system that utilizes thermal inkjet technology, the fluid composition **52** travels through the fluid channel **156** and into the inlet **184** of each fluid chamber **180**. The fluid composition **52**, which may comprise in part a volatile component, travels through each fluid chamber **128** to the heater **134** of each fluid chamber **128**. The heater **134** vaporizes at least a portion of the volatile components in the fluid composition **52**, causing a vapor bubble form. The expansion created by the vapor bubble causes a droplet of fluid composition **52** to be ejected through the nozzle **130**. The vapor bubble then collapses and causes the droplet of fluid composition **52** to break away and release from the orifice **130**. The fluid composition **52** then refills the fluid chamber **128** and the process may be repeated to atomize additional droplets of fluid composition **52**.

The fan **32** pulls air from the air inlet(s) **27** into the interior **21** of the housing in order to pressurize the air in the interior **21** of the housing **12**. Because fluid will travel from an area of high pressure to an area of low pressure, the air in the interior **21** of the housing **12** will follow the least restrictive path to reach the exterior **23** of the housing **12**. As a result, the housing **12** may be configured such that the pressurized air in the interior **21** of the housing **12** flows through the air flow channel **34** between the holder **24** and the upper portion **14** of the housing **12**. From the air flow channel **34**, the pressurized air will flow through the air flow path **46** between the outer cover **40** and the reservoir **50**. If the outer cover **40** of the cartridge **26** is not sealably engaged with the housing **12**, some air may escape through the gap between the outer cover **40** and the housing **12**. The air flow through the gap between the outer cover **40** and the housing **12** may be reduced by configuring the flow path through the air flow channel **34** and the air flow path **46** to be the path of least resistance to the exterior **23** of the housing **12**.

The air flowing through the air flow path **46** combines with the fluid composition **52** that was atomized from the microfluidic delivery member **64**. Then, the combined fluid composition **52** and air flow exit out of the orifice **42** of the outer cover **40**. The shape of the air flow path **46** may direct the air out of the orifice **42** in the same or substantially the same direction as the direction the fluid composition **52** is being dispensed from the die **92**. The air provides additional force, in addition to the force of dispensing the atomized fluid composition **52** from the microfluidic delivery member **64**, to direct the fluid composition **52** into the air.

Other ejection processes may be used in addition or in the alternative to heaters used to atomize the fluid composition **52**. For instance, piezoelectric crystal elements or ultrasonic fluid ejection elements may be used to atomize the fluid composition from the die **92**.

The output of the microfluidic delivery system **10** may be adjustable or programmable. For example, the timing between releases of droplets of fluid composition **52** from the microfluidic delivery system **10** may be any desired timing and can be predetermined or adjustable. Further, the flow rate of fluid composition released from the microfluidic delivery system **10** can be predetermined or adjustable. For example, the microfluidic delivery system **10** may be configured to deliver a predetermined amount of the fluid composition **52**, such as a perfume, based on a room size or may be configured to be adjustable as desired by the user. For exemplary purposes only, the flow rate of fluid composition **52** released from the cartridge **26** could be in the range of about 5 to about 60 mg/hour or any other suitable rate or range.

The microfluidic delivery system **10** may be used to deliver a fluid composition into the air. The microfluidic delivery system **10** may also be used to deliver a fluid composition onto a surface.

Upon depletion of the fluid composition in the reservoir **50**, the microfluidic cartridge **26** may be removed from the housing **10** and replaced with another microfluidic cartridge **26**.

All percentages stated herein are by weight unless otherwise specified.

Values disclosed herein as ends of ranges are not to be understood as being strictly limited to the exact numerical values recited. Instead, unless otherwise specified, each numerical range is intended to mean both the recited values, any integers within the specified range, and any ranges with the specified range. For example a range disclosed as "1 to 10" is intended to mean "1, 2, 3, 4, 5, 6, 7, 8, 9, 10."

The dimensions and values disclosed herein are not to be understood as being strictly limited to the exact numerical values recited. Instead, unless otherwise specified, each such dimension is intended to mean both the recited value and a functionally equivalent range surrounding that value. For example, a dimension disclosed as "40 mm" is intended to mean "about 40 mm."

Every document cited herein, including any cross referenced or related patent or application and any patent application or patent to which this application claims priority or benefit thereof, is hereby incorporated herein by reference in its entirety unless expressly excluded or otherwise limited. The citation of any document is not an admission that it is prior art with respect to any invention disclosed or claimed herein or that it alone, or in any combination with any other reference or references, teaches, suggests or discloses any such invention. Further, to the extent that any meaning or definition of a term in this document conflicts with any meaning or definition of the same term in a document incorporated by reference, the meaning or definition assigned to that term in this document shall govern.

While particular embodiments of the present disclosure have been illustrated and described, it would be obvious to those skilled in the art that various other changes and modifications can be made without departing from the spirit and scope of the invention. It is therefore intended to cover in the appended claims all such changes and modifications that are within the scope of this invention.

PATENT CITATIONS

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US6261347	Oct 30, 1998	Jul 17, 2001	Ncr Corporation	Scented jet ink and printed articles therefrom
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				Atomization method, atomizer based on

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				composition
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CLASSIFICATIONS

International Classification	A61L9/03 , B05B17/06 , A61L9/12 , A61L9/14 , B05B17/00 , B01F3/04
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