US 20170023235A1

(19) United States
(12) Patent Application Publication
(10) Pub. No.: US 2017/0023235 A1
(43) Pub. Date: Jan. 26, 2017
Ishikawa

(54) **SUBLIMATOR/VAPORIZER**

(71) Applicant: **Apple Inc.**, Cupertino, CA (US)

(72) Inventor: **Tetsuya Ishikawa**, San Jose, CA (US)

(21) Appl. No.: **15/215,313**

(22) Filed: **Jul. 20, 2016**

Related U.S. Application Data

(60) Provisional application No. 62/195,240, filed on Jul. 21, 2015.

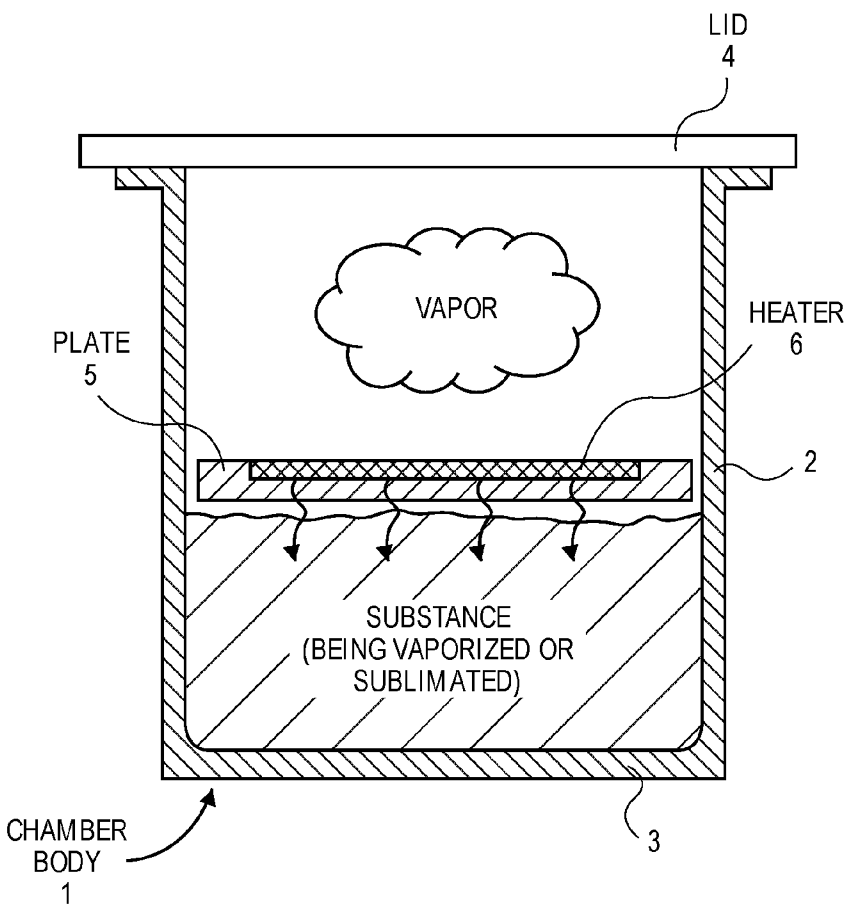
Publication Classification

(51) **Int. Cl.**
F22B 1/28 (2006.01)

(52) **U.S. Cl.**
CPC *F22B 1/284* (2013.01)

(57) **ABSTRACT**

A chamber body is to receive therein a substance that is to be vaporized or sublimated into a vapor. A plate whose bottom face rests on the substance inside the chamber body is temperature regulated, e.g., using a heater therein, which releases heat directly above the substance that lies below. The plate slides downward as the substance is consumed by vaporization or sublimation. Other embodiments are also described and claimed.



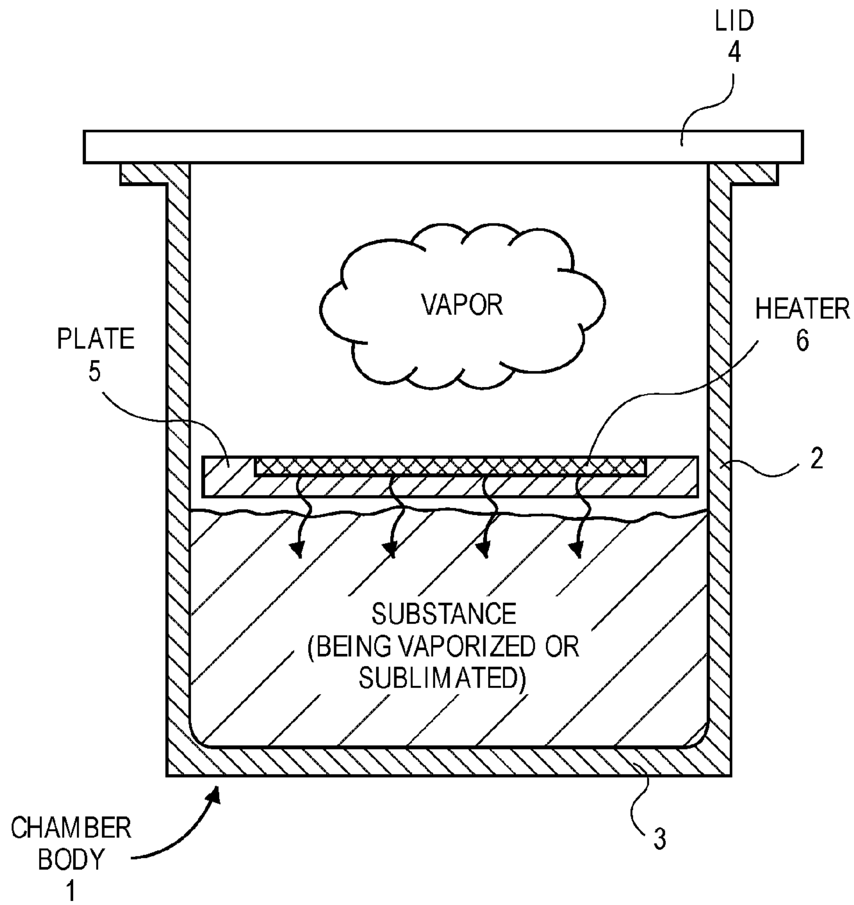

LID
4
VAPOR
HEATER
6
PLATE
5
2
SUBSTANCE
(BEING VAPORIZED OR
SUBLIMATED)
CHAMBER
BODY
1
3

FIG. 1

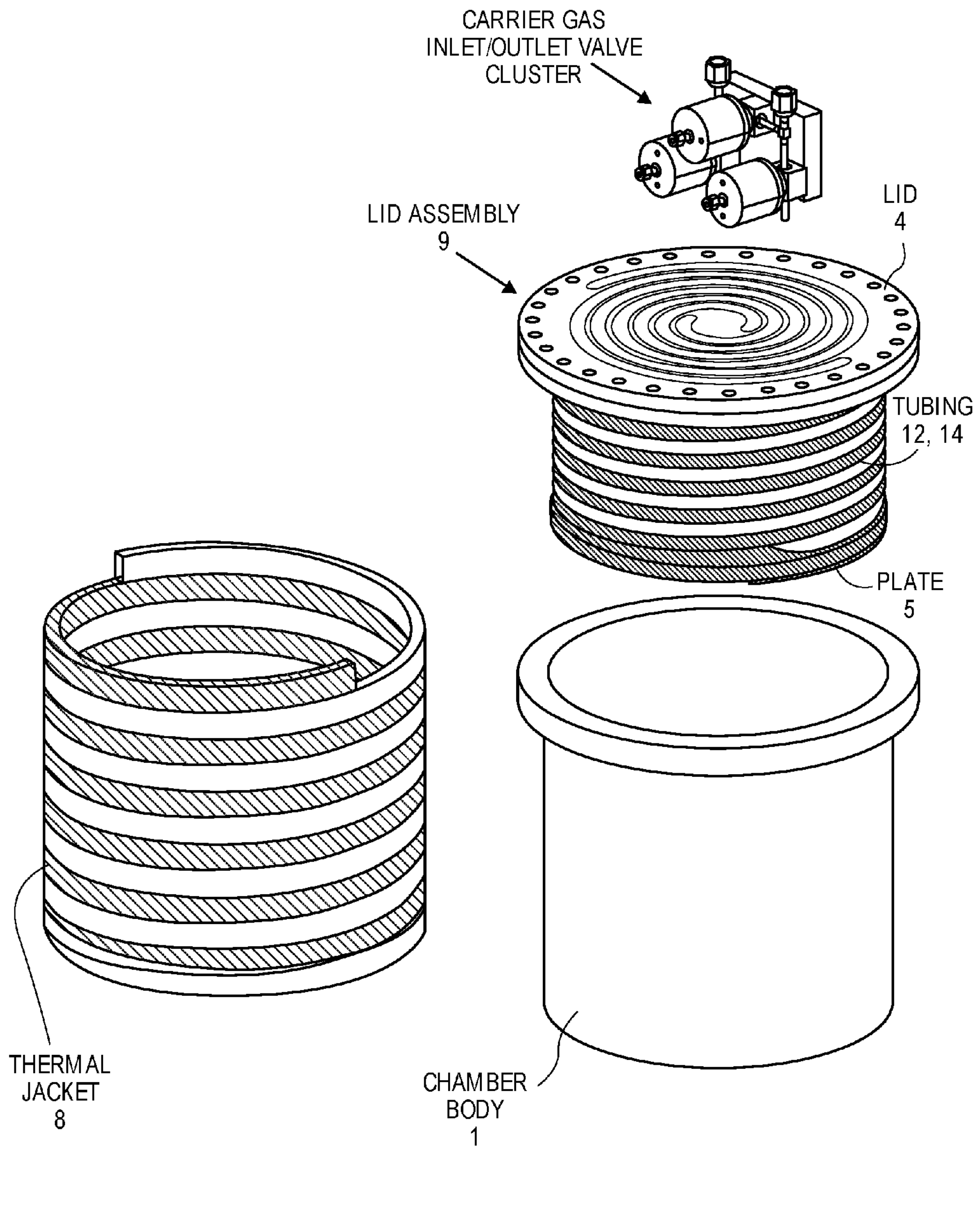

CARRIER GAS
INLET/OUTLET VALVE
CLUSTER
LID ASSEMBLY
9
LID
4
TUBING
12, 14
PLATE
5
THERMAL
JACKET
8
CHAMBER
BODY
1

FIG. 2

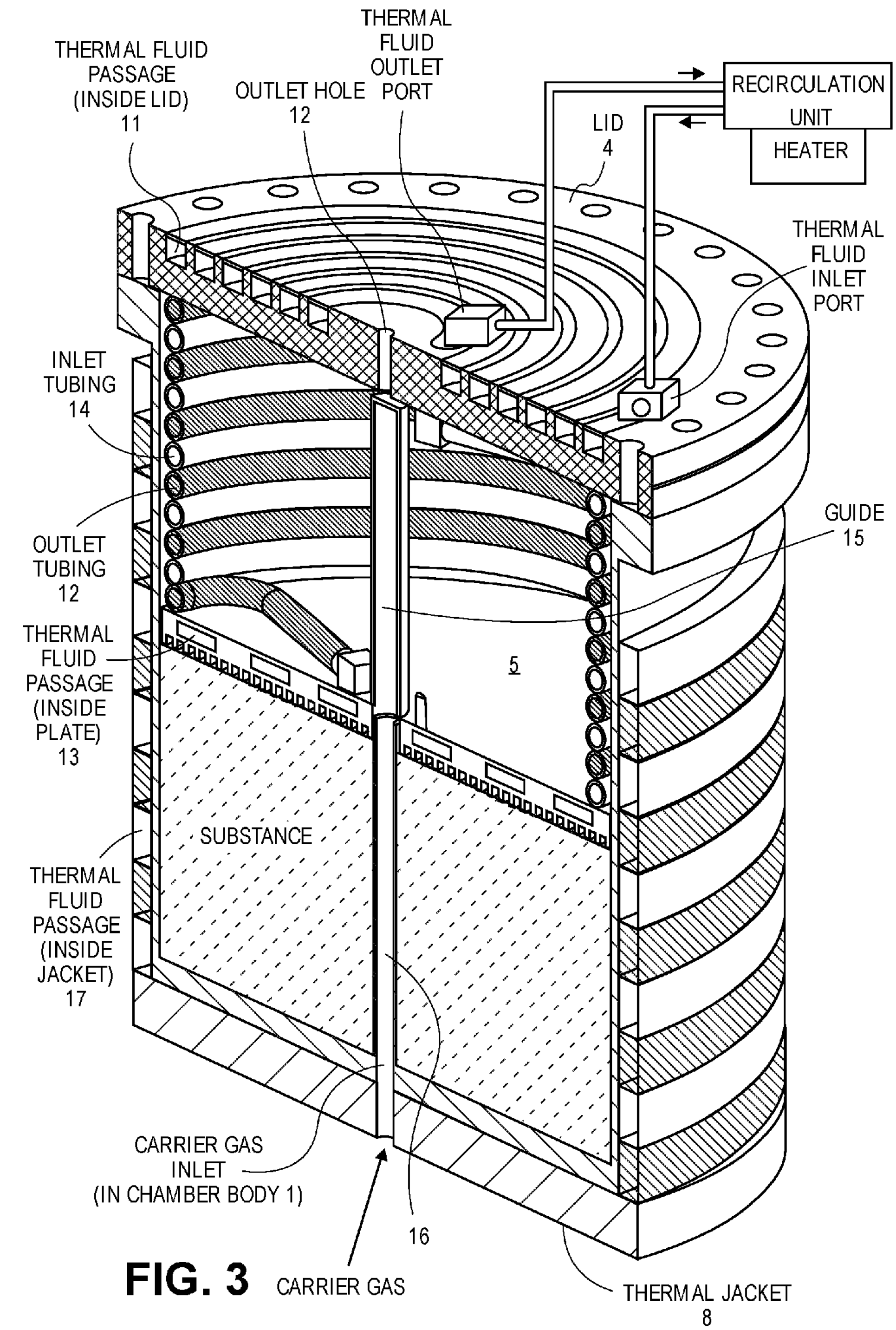

THERMAL FLUID PASSAGE (INSIDE LID) 11
OUTLET HOLE 12
THERMAL FLUID OUTLET PORT
RECIRCULATION UNIT
HEATER
LID 4
THERMAL FLUID INLET PORT
INLET TUBING 14
OUTLET TUBING 12
GUIDE 15
5
THERMAL FLUID PASSAGE (INSIDE PLATE) 13
SUBSTANCE
THERMAL FLUID PASSAGE (INSIDE JACKET) 17
CARRIER GAS INLET (IN CHAMBER BODY 1)
16
CARRIER GAS
THERMAL JACKET 8

FIG. 3

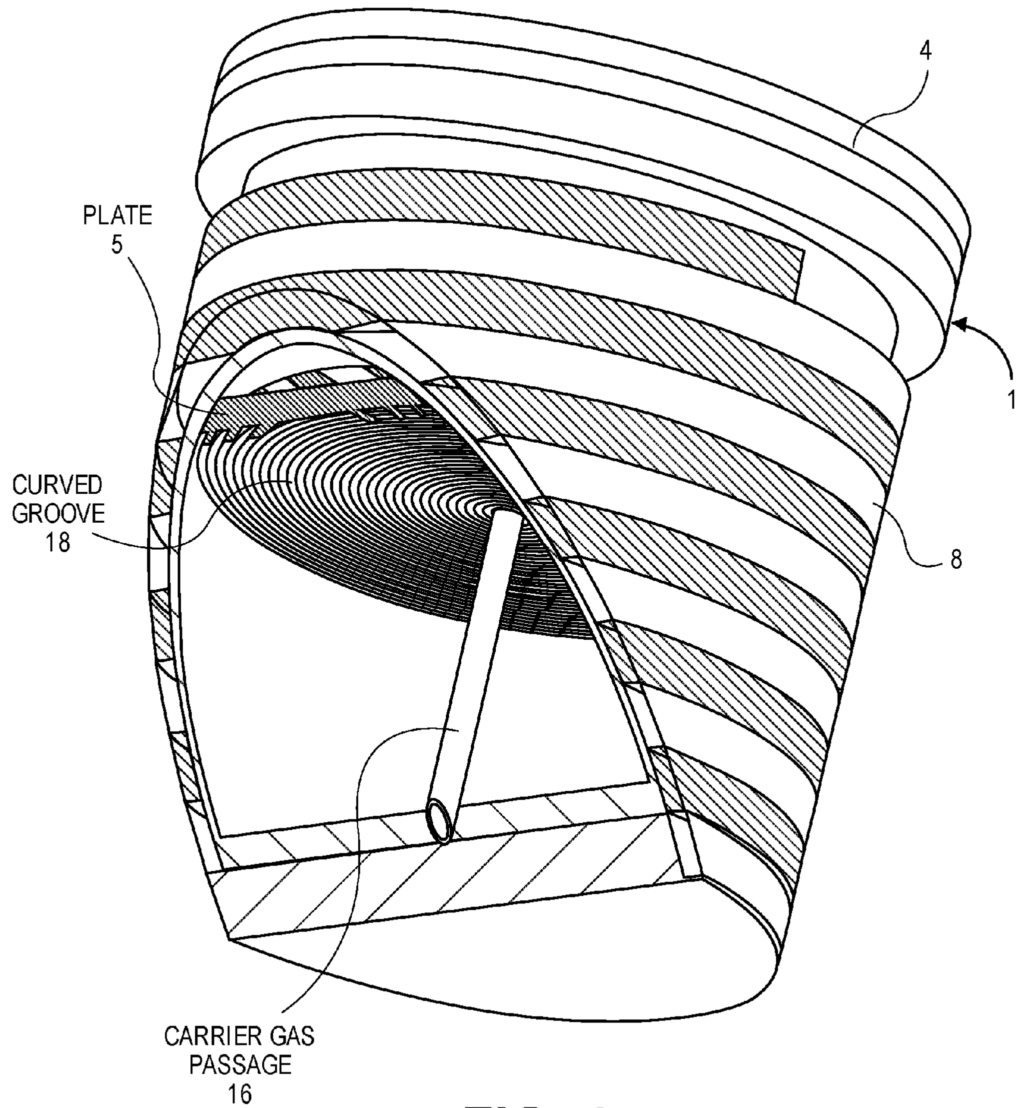


FIG. 4

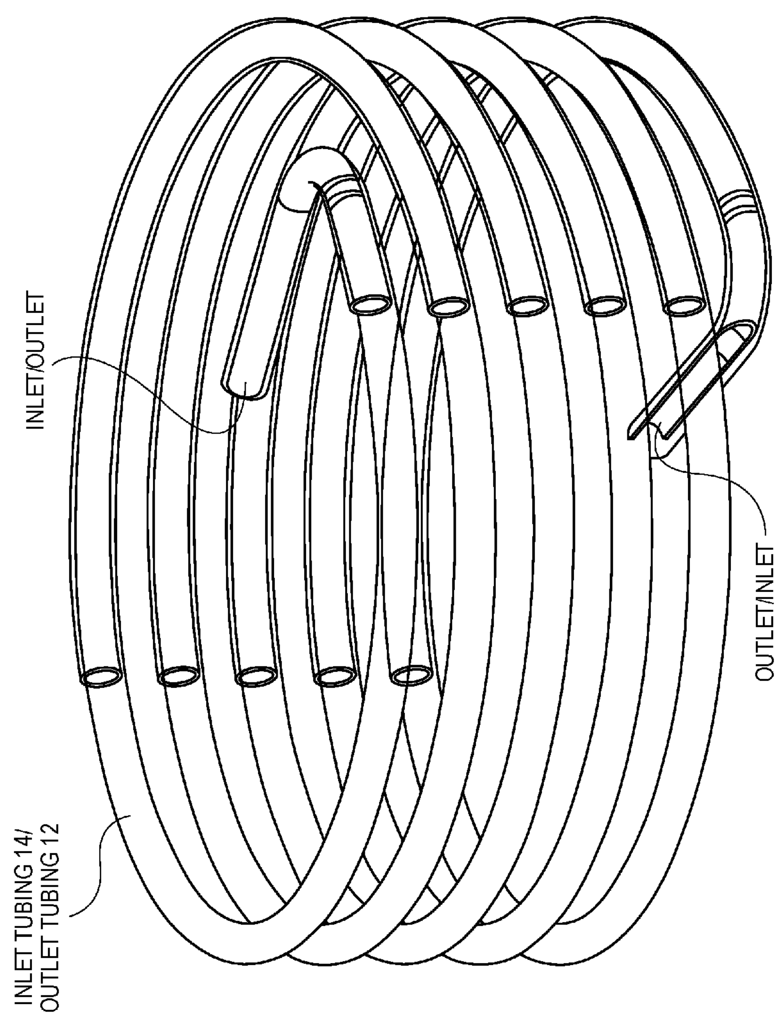


FIG. 5

SUBLIMATOR/VAPORIZER

[0001] This application claims the benefit of the earlier filing date of U.S. Provisional Application No. 62/195,240, filed Jul. 21, 2015.

BACKGROUND

[0002] In a typical sublimator or vaporizer, a substance (also referred to here as a chemical) is placed into a canister that is heated to a sufficiently high temperature that causes the substance to sublimate (solid to vapor) or vaporize (liquid to vapor), in the canister. While the substance is heated, the regions where the vapor is formed will cool, due to the latent heat of vaporization, yielding an inconsistent vaporization rate.

[0003] The approaches described above in this section are approaches that could be pursued, but not necessarily approaches that have been previously conceived or pursued. Therefore, unless otherwise indicated, it should not be assumed that any of the approaches described in this section qualify as prior art merely by virtue of their inclusion in this section.

SUMMARY

[0004] An embodiment of the invention is an apparatus for vaporization or sublimation of a substance. A chamber body (e.g., that of a canister) is to hold a substance therein that is being vaporized or sublimated. A temperature-regulated plate is moveable in the chamber body. The temperature of the movable plate is controlled by means such as a resistive heater, a radiant heater, an inductive heater or a thermoelectric heater. The bottom face of the plate rests on the substance, inside the chamber body, such that the plate releases heat directly above the substance. In this manner, heat released from the plate may supplement at least part of the energy that is lost through cooling (latent heat of vaporization) at the top surface of the substance. This may yield a consistent evaporation/sublimation environment even as the substance is consumed, because the heat releasing plate slides down with, and therefore remains adjacent to, the substance being consumed.

[0005] In one embodiment, the chamber body has a sidewall joined to a bottom, and an open top that is covered by a lid. An outlet may be formed in the lid, to draw out the vapor (where the vapor may optionally be in a mixture of vapor and a carrier gas.) The plate may be connected to the lid, e.g., through tubing in which a thermal fluid is being circulated to control temperature of the plate. Note however that the opening (of the body chamber) does not have to be located at its top; also, the plate need not be connected to the lid. As an example, the opening may be formed in a bottom of the body chamber. Also, the plate may be connected to a portion of the chamber body other than its lid assembly, e.g., its sidewall.

[0006] In one embodiment, the outermost edge of the plate may be shaped to conform to the inner surface of the sidewall of the chamber body so as to cover as much of the substance as possible while allowing the plate to slide downward within the chamber body as the substance is vaporized or sublimated.

[0007] The above summary does not include an exhaustive list of all aspects of the present invention. It is contemplated that the invention includes all systems and methods that can be practiced from all suitable combinations of the various aspects summarized above, as well as those disclosed in the Detailed Description below and particularly pointed out in the claims filed with the application. Such combinations have particular advantages not specifically recited in the above summary.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The embodiments of the invention are illustrated by way of example and not by way of limitation in the Figures of the accompanying drawings in which like references indicate similar elements. It should be noted that references to an or "one" embodiment of the invention in this disclosure are not necessarily to the same embodiment, and they mean at least one. Also, in the interest of conciseness and reducing the total number of Figures, a given Figure may be used to illustrate the features of more than one embodiment of the invention, and not all elements in the Figure may be required for a given embodiment.

[0009] FIG. **1** illustrates an embodiment of an apparatus for vaporization or sublimation of a substance.

[0010] FIG. **2** is an exploded view of an example sublimator/vaporizer having coiled inlet and outlet tubings that connect the plate to the lid.

[0011] FIG. **3** is a section view of the apparatus of FIG. **2** fitted with a carrier gas mechanism.

[0012] FIG. **4** is a cutaway view of the apparatus of FIG. **2** taken up into the chamber body.

[0013] FIG. **5** is an example of tubing used by the apparatus depicted in FIG. **2** as inlet or outlet tubing.

DETAILED DESCRIPTION

[0014] Several embodiments of the invention with reference to the appended drawings are now explained. Whenever the shapes, relative positions and other aspects of the parts described in the embodiments are not explicitly defined, the scope of the invention is not limited only to the parts shown, which are meant merely for the purpose of illustration. Also, while numerous details are set forth, it is understood that some embodiments of the invention may be practiced without these details. In other instances, well-known structures and techniques have not been shown in detail so as not to obscure the understanding of this description.

[0015] FIG. **1** illustrates an embodiment of an apparatus for vaporization or sublimation of a substance. The substance may be a solid precursor that is to be sublimated within a chamber, or it may be a liquid chemical that is to be vaporized in the chamber. The apparatus shown is composed of a chamber body **1** having a sidewall **2** that is joined to a bottom **3**, and an open top. The sidewall **2** may be cylindrical as shown for example in FIG. **2**. The chamber body **1** may be a canister, such as one that is metallic and is made of a material that can hold a substance (against the bottom **3**) that is to be vaporized or sublimated into a vapor, but that should not react with the substance. The canister may be manufactured using any suitable process, e.g., centrifugal casting. The open top of the chamber body **1**, through which the canister may be filled with the substance, may be covered by a lid **4** that once fitted in place as shown may fully enclose the chamber within the chamber body **1**. Note that during the vaporization/sublimation process, the lid **4** may remain secured to the top edge of the chamber body 1 that defines the open top, so as to seal off the chamber, e.g., render it airtight.

[0016] Inside the chamber or chamber body 1 is a plate 5 whose bottom face may rest upon the substance. The plate 5 has a heater 6 therein that releases heat directly above the substance that is below it. The plate 5 is sized and shaped such that it can slide downward within the chamber as the substance is consumed by vaporization or sublimation, but may be large enough in area to cover as much of the top surface of the substance as possible. In one embodiment, the outermost edge of the plate 5 extends to and is shaped to conform to the inner surface of the sidewall 2 of the chamber body 1 (e.g. as a circle), while allowing the plate 5 to slide downward within the chamber body (as the substance is vaporized or sublimated). In this manner, heat released from the plate 5 may efficiently supplement at least part of the energy that is lost through cooling along virtually the entire surface of the substance (latent heat vaporization.) This takes place continuously while the substance is consumed, to render an efficient vaporization/sublimation process.

[0017] In one embodiment, there may be enough pressure developed within a gap between the top surface of the substance and the bottom face of the plate 5 such that the plate 5 may lift slightly above the substance. Thus, although the plate 5 is described as initially resting on the substance so that it may tap the top surface of the substance flat, it may also "float" during vaporization or sublimation.

[0018] Although not shown in FIG. 1, any suitable technique may be used to draw out the vapor (e.g., as a mixture together with a carrier gas) from the chamber, depending upon certain factors including the vapor pressure of the substance. For example, an outlet hole 12 may be formed in the lid 4 (not shown in FIG. 1, but see the embodiment of FIG. 3 described below) through which the vapor is drawn out of the chamber. Although not shown, a mist or solid separator may be present at the outlet hole 12, to prevent the formation of any solid that could block the outlet hole 12.

[0019] Turning now to FIG. 2, this is an exploded view of an example embodiment of the apparatus for vaporization or sublimation of a substance. Several mechanisms are shown that may assist in providing an isothermal condition for the vaporization/sublimation process. First, a thermal jacket 8 may surround the chamber body 1 (see also FIG. 3 which shows the thermal jacket 8 in place.) The thermal jacket 8 helps maintain an isothermal condition by releasing heat into the adjacent sidewall 2 of the chamber body 1. The thermal jacket 8 may have an internal passage 17 therein—see FIG. 3—through which thermal fluid is to circulate during the process. In one embodiment, the passage 17 forms a spiraling channel that spirals and surrounds the sidewall 2 and may extend the full height, in a vertical direction, as shown, of the chamber body 1. Thermal fluid circulates within the passage 17, e.g., through plumbing and propelled by a pump that are not shown, in order to raise the temperature of the chamber body 1 to help achieve vaporization or sublimation of the substance, and maintain an isothermal condition. The thermal jacket 8 and its internal thermal fluid passage 17 may also extend across the bottom 3 of the chamber body 1 to further help maintain the isothermal condition across the entirety of the chamber body 1. The thermal fluid may be temperature-controlled to help maintain a consistent vaporization/sublimation process temperature (as the rate of vaporization/sublimation may depend on the temperature).

[0020] Another aspect that is shown in FIG. 2 is a lid assembly 9 that is composed of the lid 4 to which the plate 5 is connected through inlet tubing 14 and outlet tubing 12. A thermal fluid sourced from outside of the canister is to circulate through the inlet tubing 14, into a passage 13 in the heater 6 within the plate 5—see FIG. 3—and then out through the outlet tubing 12. This is an embodiment in which the heater 6 is a radiant heater. A recirculation unit and fluid heater may be provided outside of the chamber body 1 that is coupled to the inlet and outlet tubings 14, 12 via respective ports formed in the lid 4, to regulate the flow of the thermal fluid that is circulating so as to maintain an isothermal condition within the chamber body 1, and especially within the boundary region that is between the top of the substance and the bottom face of the plate 5. As seen in FIG. 3, a thermal fluid passage 11 may also be formed in the lid 4 that may serve to more efficiently transfer heat to the lid 4, by circulating the thermal fluid throughout the lid 4 prior to the fluid then exiting the lid and passing into the inlet tubing 14.

[0021] In one embodiment, the lid 4 has a fluid inlet port that is connected to an upper end (inlet) of the inlet tubing 14, while a lower end (outlet) of the inlet tubing 14 is connected to an inlet of the internal fluid passage 13 that is formed in the plate 5. Similarly, outlet tubing 14 has an upper end (outlet) that is connected to a fluid outlet port in the lid 4, and a lower end (inlet) that is connected to an outlet of the internal fluid passage 13 formed in the plate 5. This enables the thermal fluid to be circulated as follows: into the canister through an inlet port or orifice in the lid 4 (not shown), through the passage 11 in the lid 4, and then out of the lid 4 and into the inlet tubing 14, and then into the passage 13 where it circulates through the plate 5, and then exits the plate 5 and passes into the outlet tubing 12, and then out of the canister through an outlet port or orifices in the lid 4 (not shown). The inlet tubing 14 thus brings a heat transfer or thermal fluid from the lid 4 down into the passage 13 that is formed within the plate 5, which by virtue of heat transfer thus acts as the heater 6 which is across the top surface of the substance being sublimated or vaporized (see FIG. 1). The thermal fluid is returned to the lid 4 through the outlet tubing 14.

[0022] The inlet tubing 14 and the outlet tubing 12 may each be structured, as also shown in FIG. 5, as coiled tubing or a coil that fits inside the chamber. The coiled tubing or coil is compressed or shortened initially (before the substance is consumed by vaporization or sublimation), but then expands (lengthens) as the plate 5 slides downward due to the substance being consumed. That occurs because the plate 5 is attached to and therefore pulls down on the lower ends of the inlet and outlet tubing 14, 12, e.g. due to gravity alone, as the substance is consumed. In this manner, circulation of the thermal fluid through the heater 6 of the plate 5 is maintained continuously during the vaporization/sublimation process.

[0023] Note, however, that in other embodiments, the heater 6 may be different than a thermal fluid radiator. For example, the heater 6 may be an infrared lamp, a resistive device heater, or an inductive element heater. In such instances, there may be no need for the inlet and outlet tubing 14, 12 since there is no thermal fluid that is being circulated through the plate 5.

[0024] Returning to the embodiments shown in FIG. 2 and FIG. 3, where tubing 12, 14 may be attached to the lid 4 (to form a lid assembly 9) and that serves to heat the plate 5, it can be seen that each tubing **12**, **14** is wound as a spiral, where the resulting coil becomes taller in the vertical direction while the face of the plate **5** remains horizontal as the plate **5** moves downward, as best seen in FIG. **3**. As also depicted in the perspective view of FIG. **5**, the inlet tubing **14** is formed as a coil and has a number of inlet rings. Similarly, the outlet tubing **12** is also formed as a coil and has a number of outlet rings. The two coils are arranged "within" each other such that the inlet and outlet rings are interleaved, or the inlet and outlet rings together form an alternating sequence, as best seen in FIG. **2** and in FIG. **3**. The entireties of the inlet and outlet tubing **14**, **12** are positioned inside the chamber body **1** (once the lid **4** has been fitted to close off the open top of the chamber). This may be done by lowering the lid assembly **9**—see FIG. **2**—into the chamber body **1**, where the lid assembly **9** in this example also includes the plate **5** as attached to the lower ends (inlet and outlet) of the tubing **12**, **14**. Also, in the particular embodiment depicted in FIG. **3**, note how the inlet and outlet rings conform to the inner surface of the sidewall **2**, which in this case is cylindrical such that the rings are circular and are positioned adjacent to the sidewall **2**. The rings may even touch the inside surface sidewall **2** along their outer perimeters, although there should be a small enough gap between the rings and the sidewall **22** that allows the coils to expand freely (lengthwise) as the plate **5** moves downward due to force of gravity alone (assuming the plate **5** is heavy enough to overcome the sum of the spring forces of the two, coiled tubings **14**, **12**.)

[0025] The embodiment depicted in FIG. **2** and in FIG. **3** may also be described as having inlet tubing **14** and outlet tubing **12** that are inside the chamber body **1** and that are wound as spirals, respectively. Both of the tubings **14**, **12** simultaneously become taller, in the vertical direction, as the plate **5**, while remaining in a horizontal or flat orientation, moves downward. Both tubings **14**, **12** become shorter simultaneously, in the vertical direction, when the plate is pushed upward. In this regard, FIG. **2** shows the plate **5** in its full upward position where the coils are compressed to such an extent that there is essentially no gap between adjacent inlet and outlet rings. This fully compressed state of the coils may not be the "natural" state of the lid assembly **9** if it were fitted to the chamber body **1** as in FIG. **3**. FIG. **2** should be understood as depicting the situation where the plate **5** is resting on a surface and the lid **4** is heavy enough and is free to move downward as far as needed until the tubing **12**, **14** has become fully compressed as shown.

[0026] Referring now to FIG. **3**, as seen in this section view, an outlet hole **12** is formed in the lid **4** through which vapor (produced by the sublimation/vaporization of the substance in the chamber) may be drawn out of the chamber. If the substance has high enough vapor pressure, then the vapor out flow may be direct or self-propelled, and may be controlled through an orifice device (not shown, but in most instances located outside of the chamber body **1**, along with associated plumbing). In that case, there may be no need for pumping a carrier gas into the chamber, to transport the vapor through the external plumbing. If, however, the substance does not have a high enough vapor pressure to enable its vapor to self propel directly through the external plumbing, then as seen in FIG. **3**, a carrier gas passage **16** may be provided through which a carrier gas may be pumped into the chamber. An inlet/outlet control valve cluster as shown in FIG. **2** may serve to control inlet flow of the carrier gas and outlet flow of the vapor-carrier gas mixture. The carrier gas mixes with vapor in the chamber, and the mixture may be drawn out of the chamber body **1**, e.g., through the outlet hole **12** in the lid **4**. The carrier gas may be an inert gas such as argon, nitrogen, helium or other inert gas that is non-reactive relative to the substance.

[0027] In one embodiment, the carrier gas passage **16** is composed of a telescopic tube that extends from the bottom **3** of the chamber body **1** upward to the bottom face of the plate **5**, as shown. The bottom end of the telescopic tube communicates with a hole in the bottom **3** of the chamber body **1**, which is an inlet port for the carrier gas. As the plate **5** descends (due to the substance being consumed), the carrier gas passage **16** shortens, for example as a telescopic tube would, while allowing the carrier gas to flow unimpeded and to mix with the vapor that is being produced at the top surface of the substance between the substance and the bottom face of the plate **5** (while bypassing contact with the substance below.)

[0028] Note here that the heat produced by the carrier jacket **8**, and the fact that the carrier gas passage **16** (e.g., a telescopic tube) is surrounded by the substance which is being heated, in effect helps preheat the carrier gas before the carrier gas mixes with the vapor. This may improve consistency of saturation of the vapor (within the carrier gas). This allows for efficient transport of the vapor out of the chamber (through the outlet hole **12**) as the mixture of the vapor and the carrier gas fills the space in the chamber above the plate **5** and is drawn out through the outlet hole **12**.

[0029] In some embodiments, a guide **15** may be added to help locate the plate **5**, as it descends down. A hole may be formed in the plate **5** through which the guide **15** extends. In the embodiment of FIG. **3**, this hole is formed in the center region of the plate **5** and may be aligned directly above the hole that is formed in the bottom of the chamber body **1**, which acts as an inlet for the carrier gas (and that is communicating with the bottom end of the carrier gas passage **16**). The guide **15**, however, may be located elsewhere, and there may be more than one guide **15** to for example help keep the plate **5** level (as it descends within the chamber). The guide **15** may also be a telescopic structure that extends from the top of the plate **5** to the maximum height of the plate **5**, when the greatest amount of the substance is present in the chamber, and may have a larger diameter than that of the carrier gas passage **16**.

[0030] In one embodiment, one or more grooves may be formed in the bottom face of the plate **5** that extend outward, e.g., from the center region of the plate **5** to an outermost region of the plate **5**. This provides increased surface area for the vapor, which may assist in improved mixing of the vapor and the carrier gas below the plate **5**, as the flow of the mixture is guided along a sufficient groove length (or a number of distinct grooves) that may enable the carrier gas to be more fully saturated with the vapor by the time it reaches the outermost edge of the plate **5** and then seeps up and across the plate **5** (to fill the space above the plate **5** inside the chamber). The saturated carrier gas may then be drawn out through the outlet hole **12**—see FIG. **3**.

[0031] As an example, referring now to FIG. **4**, a curved groove **18** may be formed that spirals outward as shown, from the center region of the plate **5** to an outermost edge region of the plate **5**. Other, non-curved patterns are possible for one or more grooves that serve the above purpose of improving mixing and saturation of the carrier gas with the vapor.

[0032] A process for vaporization/sublimation may proceed as follows. A canister is filled with a substance to be vaporized or sublimated. The plate **5** is lowered into the canister, and rests on top of the substance. The canister is closed off (sealed) and the temperature of the plate is raised and controlled to a desired level, e.g., by passing thermal fluid through a passage in the plate. A carrier gas is introduced into the canister, e.g., though the bottom of the canister into a carrier gas passage (e.g., a telescopic tube) that extends through the substance, to the bottom face of the plate. The carrier gas emerges at the top end of the telescopic tube where it then mixes with the vapor below the bottom surface of the plate, and the vapor-gas mixture emerges past the side or edge of the plate into a space above the plate (inside the canister). The vapor-gas mixture is drawn (e.g., pumped) out of the canister through an outlet (e.g., formed in a lid at the top of the canister). In the meantime, the temperature of the plate and that of the canister as a whole may be regulated to ensure an isothermal condition for the vaporization/sublimation process, and to improve consistency of the process by maintaining a desired temperature between the plate and the top of the substance (through regulation of the heat released by the plate). As the substance is consumed, and vapor-gas mixture continues to be drawn out of the canister, and the plate, which is moveable, essentially maintains its horizontal orientation and adjacent position against a top surface of part of the substance, and moves downward (e.g. due to gravity alone) as the top level of the substance drops. The vaporization/sublimation process may therefore be more consistent even as the substance continues to be consumed.

[0033] Another embodiment of an apparatus for vaporization or sublimation of a chemical includes a chamber body whose bottom is moveable, relative to the temperature regulated plate, as compared to the embodiments described above in which the bottom is joined to the sidewall of the chamber body. The substance or chemical is held against the bottom of the chamber body. In this embodiment, the plate may remain fixed in position inside the chamber body during the vaporization or sublimation. Initially, the plate (e.g., its bottom surface) may be in contact with a surface of the chemical. As the vaporization or sublimation process takes place, the chemical is consumed and its surface will otherwise drop away from the plate, except that a mechanism for maintaining surface contact between the surface of the chemical and the plate is also provided. An example of such a mechanism is a syringe that operates to move the bottom of the chamber body upward (e.g., pushes upward against the bottom, or the plunger and tube of the syringe form part of the chamber body including its bottom), as the chemical is consumed during the sublimation or vaporization. Another example is an inflatable bellows that lifts the bottom of the chamber body upward, as the chemical is consumed during the sublimation or vaporization. Yet another example of a mechanism that can push the plate upward is a diaphragm.

[0034] While certain embodiments have been described and shown in the accompanying drawings, it is to be understood that such embodiments are merely illustrative of and not restrictive on the broad invention, and that the invention is not limited to the specific constructions and arrangements shown and described, since various other modifications may occur to those of ordinary skill in the art. For example, the same heating fluid may be circulated through all of the thermal fluid passages shown in FIG. **3**, including the passage **11** inside the lid **4**, the inlet and outlet tubings **14**, **12**, the thermal fluid passage **13** inside the plate **5**, and the passage **17** inside the thermal jacket **8**. Alternatively, there may be separate plumbing provided for some or all of these thermal fluid passages, which connect to separate thermal fluid sources (pumps) and valves, to control the isothermal condition. For example, the thermal jacket **8** may be controlled independently of the heater **6** within the plate **5**. The description is thus to be regarded as illustrative instead of limiting.

What is claimed is:

1. An apparatus for vaporization or sublimation of a substance, comprising:

a canister having a chamber body in which a substance is to be held for vaporization of sublimation; and

a plate moveably positioned in the chamber body, the plate having a fluid passage formed therein;

inlet tubing located inside the chamber body and having an inlet and an outlet, wherein the inlet is connected to a fluid inlet port in the canister, and the outlet is connected to the fluid passage in the plate; and

outlet tubing located inside the chamber body and having an inlet and an outlet, wherein the inlet is connected to the fluid passage in the plate and the outlet is connected to a fluid outlet port in the canister, wherein a fluid is to circulate through the inlet tubing, the fluid passage in the plate, and the outlet tubing.

2. The apparatus of claim **1** wherein the canister further comprises a lid at a top of the canister,

wherein the fluid inlet port in the canister, to which the inlet tubing is connected, is formed in the lid, and the fluid outlet port in the canister, to which the outlet tubing is connected, is also formed in the lid.

3. The apparatus of claim **1** wherein portions of the inlet tubing and the outlet tubing that are inside the chamber body are formed as coils, respectively, wherein the coils are compressed initially and then lengthen as the plate moves downward in the chamber body.

4. The apparatus of claim **3** wherein the portion of the inlet tubing that is formed as a coil has as inlet rings, and the portion of the outlet tubing that is formed as a coil has outlet rings, wherein the inlet and outlet rings of the coils are interleaved.

5. The apparatus of claim **4** wherein the chamber body has a cylindrical sidewall, the portion of the inlet tubing that is formed as a coil has a plurality of inlet rings, and the portion of the outlet tubing that is formed as a coil has a plurality of outlet rings, wherein the outside edge of each of the inlet and outlet rings conforms to the inner surface of the cylindrical sidewall.

6. The apparatus of claim **4** wherein an outermost edge of the plate extends to and is shaped to conform to the inner surface of a sidewall of the chamber body while allowing the plate to slide downward within the chamber body as the substance is vaporized or sublimated.

7. The apparatus of claim **3** wherein the plate is to move downward due to gravity alone, as the substance in the chamber body is vaporized or sublimated.

8. The apparatus of claim **1** further comprising a thermal jacket outside of, and that surrounds or covers a sidewall of, the chamber body.

9. The apparatus of claim **1** further comprising:

an outlet hole formed in the canister through which a vapor, into which the substance has been vaporized or sublimated, is to be drawn out of chamber body; and

a carrier gas passage formed in the canister and through which a carrier gas is to be introduced into the chamber body, wherein the carrier gas is to mix with the vapor and be drawn out of the chamber body through the outlet hole.

10. The apparatus of claim **9** wherein the outlet hole is formed in the lid.

11. An apparatus for vaporization or sublimation of a substance, comprising:

a chamber body having a sidewall joined to a bottom, and an open top, the chamber body to hold a substance at the bottom that is to be vaporized or sublimated into a vapor;

a plate whose bottom face is to rest on the substance inside the chamber body, the plate having a heater therein that is to release heat directly above the substance that lies below, wherein the plate slides downward as the substance is consumed by vaporization or sublimation;

a lid that covers the open top of the chamber body; and

a telescoping tube having an inlet connected to a hole in the bottom of the chamber body and through which a carrier gas is to be introduced from outside the chamber body, the telescoping tube having an outlet for the carrier gas that is positioned between the bottom face of the plate and a top surface of the substance inside the chamber body.

12. The apparatus of claim **11** further comprising:

a plate guide that extends through a hole formed in the plate and is to guide the plate when the plate slides downward within the chamber body; and

an outlet hole formed in the lid, wherein a mixture of the carrier gas and the vapor is to be drawn out of the chamber body through the outlet hole.

13. The apparatus of claim **12** wherein the hole in the plate through which the plate guide extends is aligned directly above the hole that is formed in the bottom of the chamber body.

14. The apparatus of claim **11** further comprising:

inlet tubing located inside the chamber body that is connected to the fluid passage in the plate; and

outlet tubing located inside the chamber body that is connected to the fluid passage in the plate, wherein a fluid is to circulate through the inlet tubing, the fluid passage in the plate, and the outlet tubing.

15. The apparatus of claim **14** wherein portions of the inlet tubing and the outlet tubing inside the chamber body are wound as spirals, respectively, wherein the inlet and outlet tubing become taller and shorter in a vertical direction as the plate remains horizontal while moving downward and upward, respectively, in the chamber body.

16. The apparatus of claim **15** wherein the portion of the inlet tubing that is wound as a spiral and the portion of the outlet tubing that is wound as a spiral are interleaved in the vertical direction.

17. The apparatus of claim **14** wherein the chamber body has a cylindrical sidewall, and wherein the portions of the inlet and outlet tubings that are wound as spirals, respectively, follow the inner surface of the cylindrical sidewall.

18. The apparatus of claim **14** wherein an outermost edge of the plate extends to and is shaped to conform to the inner surface of a sidewall of the chamber body while allowing the plate to slide downward within the chamber body as the substance is vaporized or sublimated.

19. The apparatus of claim **14** wherein the temperature of the plate is controlled by the heater, which is one of a resistive heater, radiant heater, an inductive heater, or a thermoelectric heater.

20. An apparatus for vaporization or sublimation of a substance, comprising:

a chamber body having a sidewall whose bottom end is joined to a closed bottom, and whose top end defines and an open top, together enclosing a space in which a substance is to be held that is to be vaporized or sublimated into a vapor;

a plate whose bottom face is to rest on the substance inside the chamber body, the plate having a heater therein that is to release heat directly above the substance that lies below, wherein the plate slides downward as the substance is consumed by vaporization or sublimation, and wherein a groove is formed in the bottom face of the plate and that extends outward from a center region of the plate to an outermost edge region of the plate;

a lid that covers the open top of the chamber body; and

a telescoping tube having an inlet connected to a hole in the bottom of the chamber body and through which a carrier gas is to be introduced from outside the chamber body, the telescoping tube having an outlet for the carrier gas that is positioned between the bottom face of the plate and a top surface of the substance inside the chamber body.

21. The apparatus of claim **20** wherein the groove is curved and spirals outward from the center region of the plate to the outermost edge region of the plate.

22. The apparatus of claim **20** wherein the groove is curved and spirals outward from the center region of the plate to the outermost edge region of the plate where a mixture of the carrier gas and the vapor escape into the space inside the chamber body that is above the plate.

* * * * *