US 20060099344A1

(19) **United States**

(12) **Patent Application Publication**

(10) **Pub. No.: US 2006/0099344 A1**

(43) **Pub. Date: May 11, 2006**

Boroson et al.

(54) **CONTROLLING THE VAPORIZATION OF ORGANIC MATERIAL**

(75) Inventors: **Michael L. Boroson**, Rochester, NY (US); **Michael Long**, Hilton, NY (US); **Jeremy M. Grace**, Penfield, NY (US); **Jinmei Zhang**, Pittsford, NY (US); **Bruce E. Koppe**, Caledonia, NY (US); **Thomas W. Palone**, Rochester, NY (US); **Neil P. Redden**, Sodus Point, NY (US)

Correspondence Address:
Pamela R. Crocker
Patent Legal Staff
Eastman Kodak Company
343 State Street
Rochester, NY 14650-2201 (US)

(73) Assignee: **Eastman Kodak Company**

(21) Appl. No.: **10/984,095**

(22) Filed: **Nov. 9, 2004**

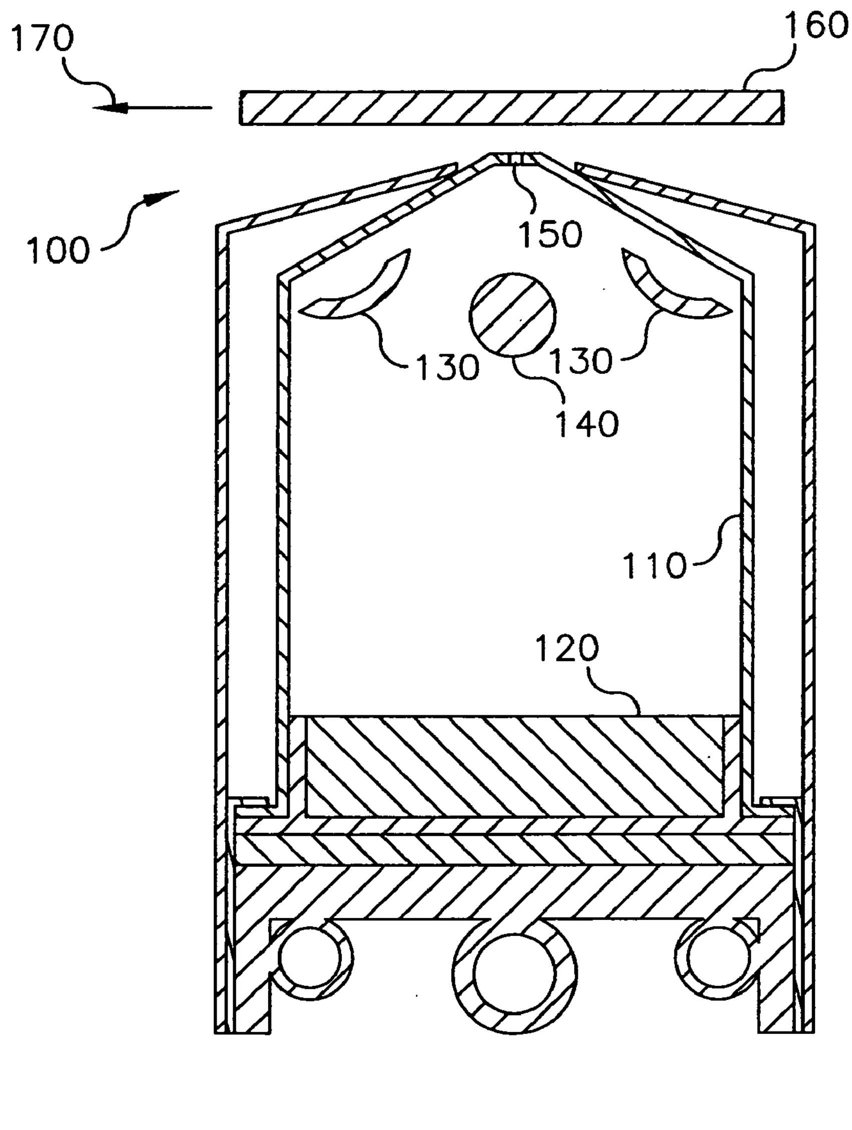
Publication Classification

(51) **Int. Cl.**
B05D 5/06 (2006.01)
C23C 16/00 (2006.01)

(52) **U.S. Cl.** **427/255.6**; 427/66; 118/726

(57) **ABSTRACT**

A method for controlling the deposition of vaporized organic material onto a substrate surface, includes providing a manifold having at least one aperture through which vaporized organic material passes for deposition onto the substrate surface; and providing a volume of organic material and maintaining the temperature of such organic material in a first condition so that its vapor pressure is below that needed to effectively form a layer on the substrate, and in a second condition heating a volume percentage of the initial volume of such organic material so that the vapor pressure of the heated organic material is sufficient to effectively form a layer.



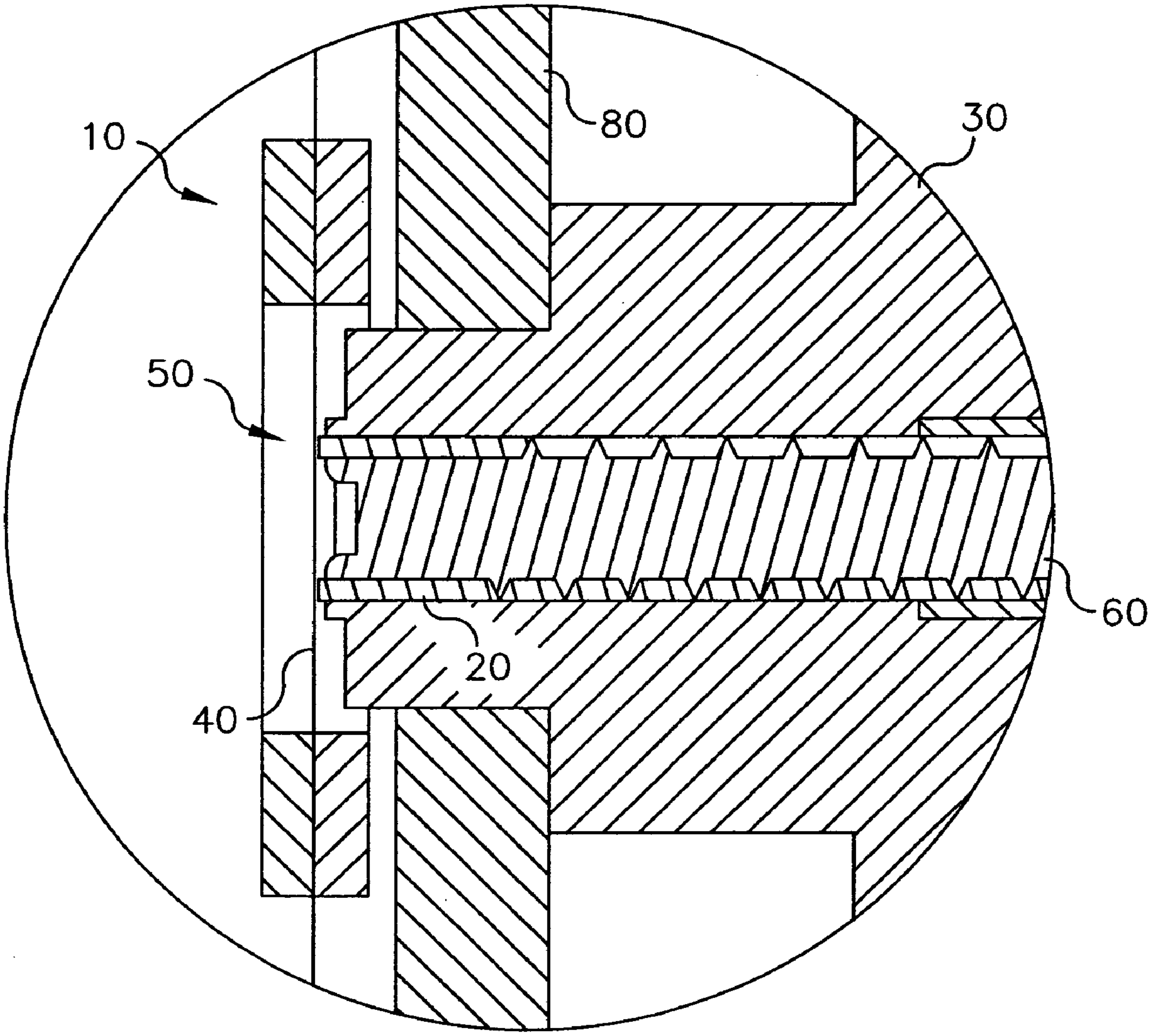


FIG. 1

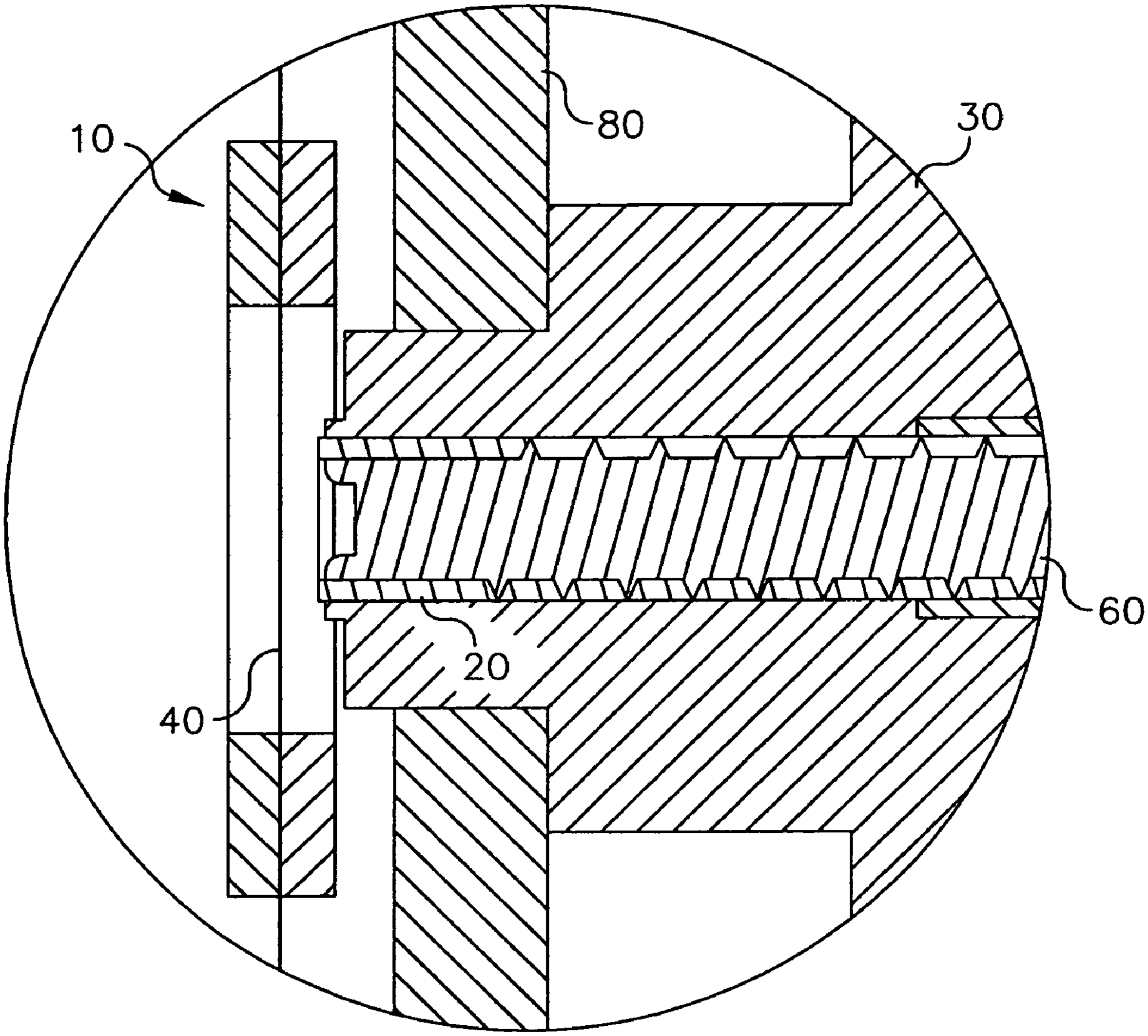


FIG. 2

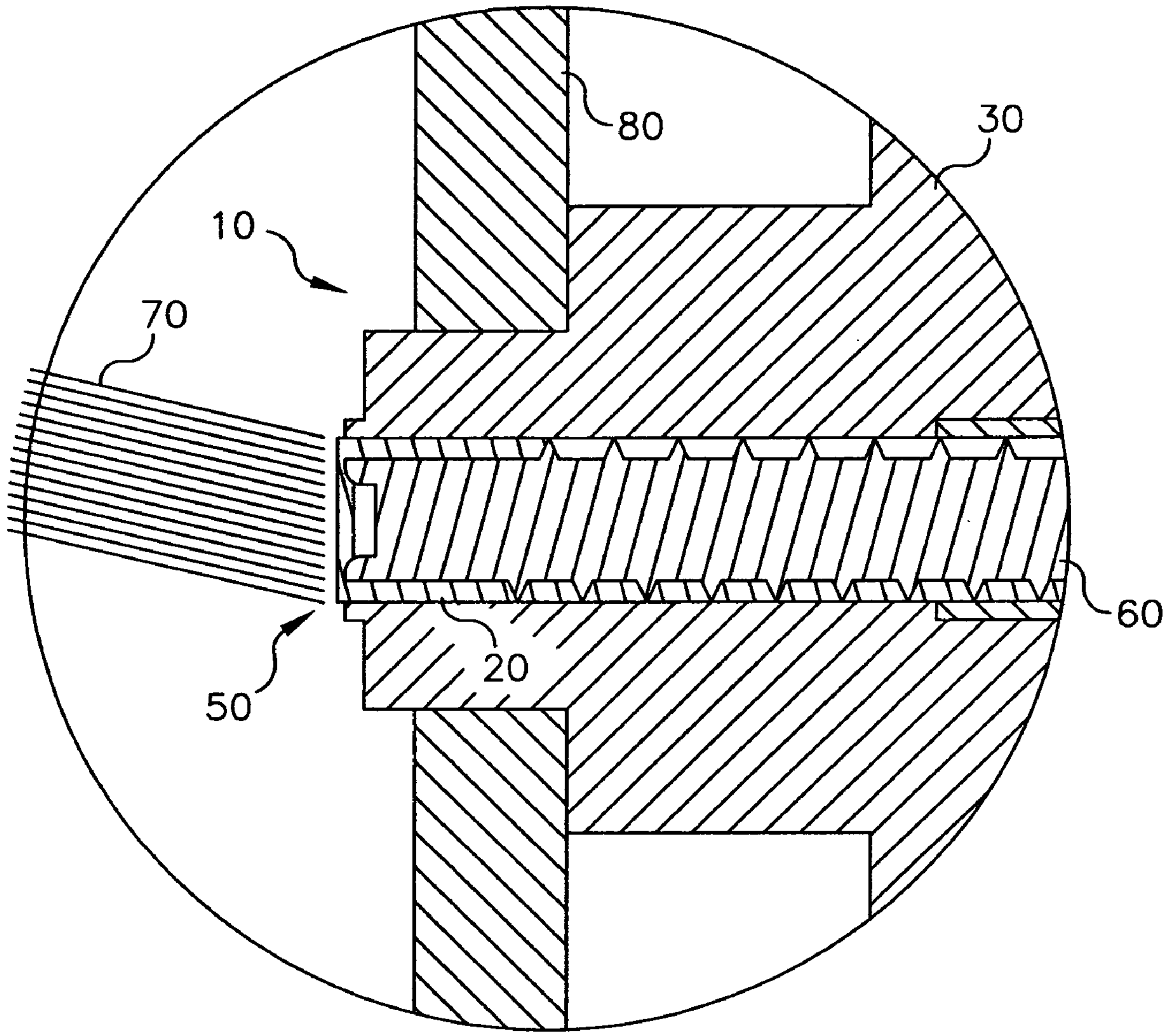


FIG. 3

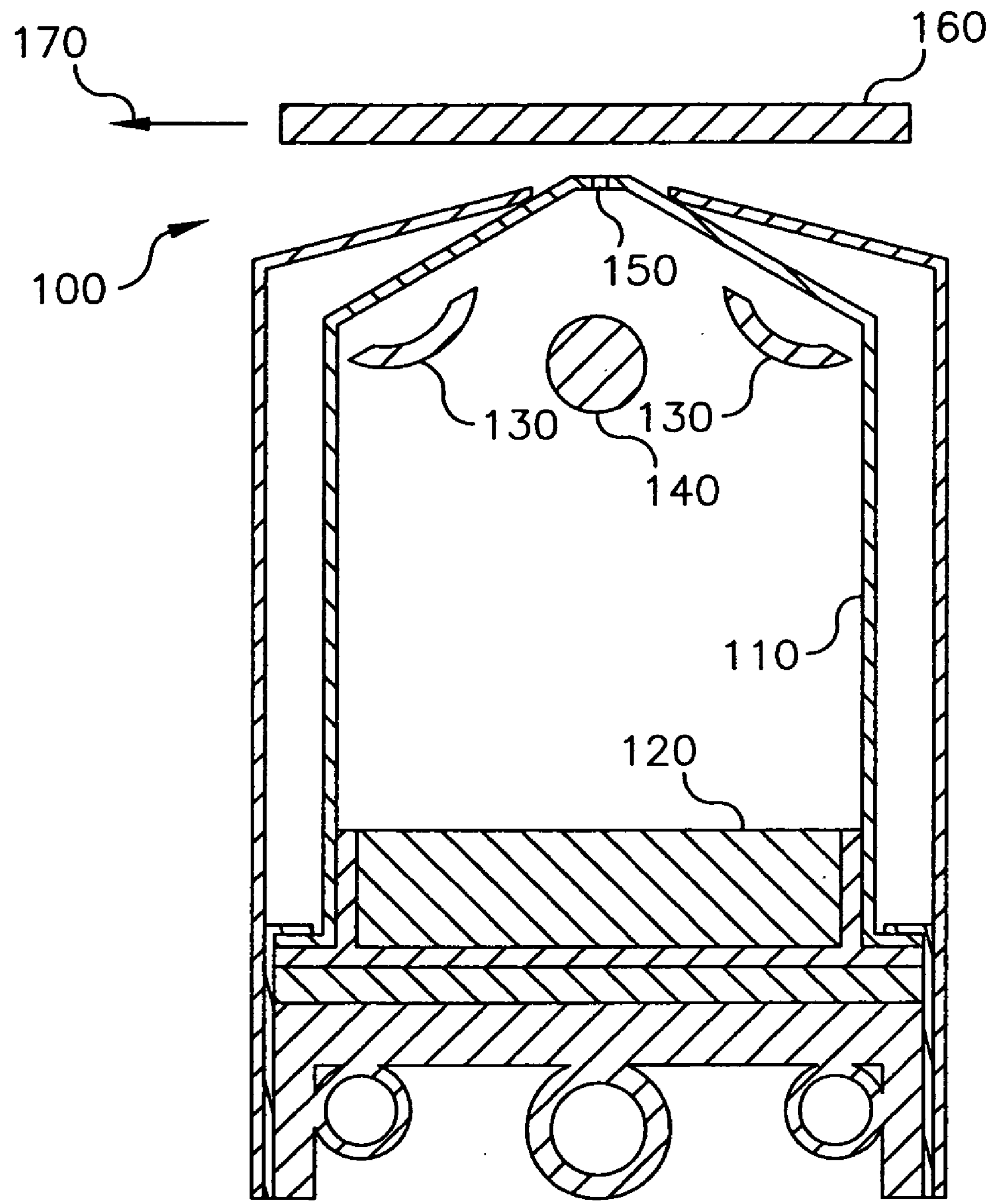
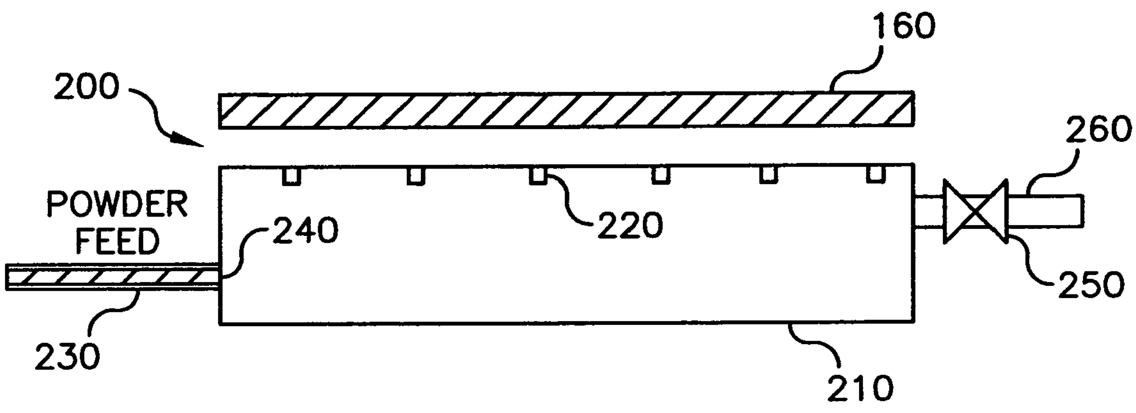
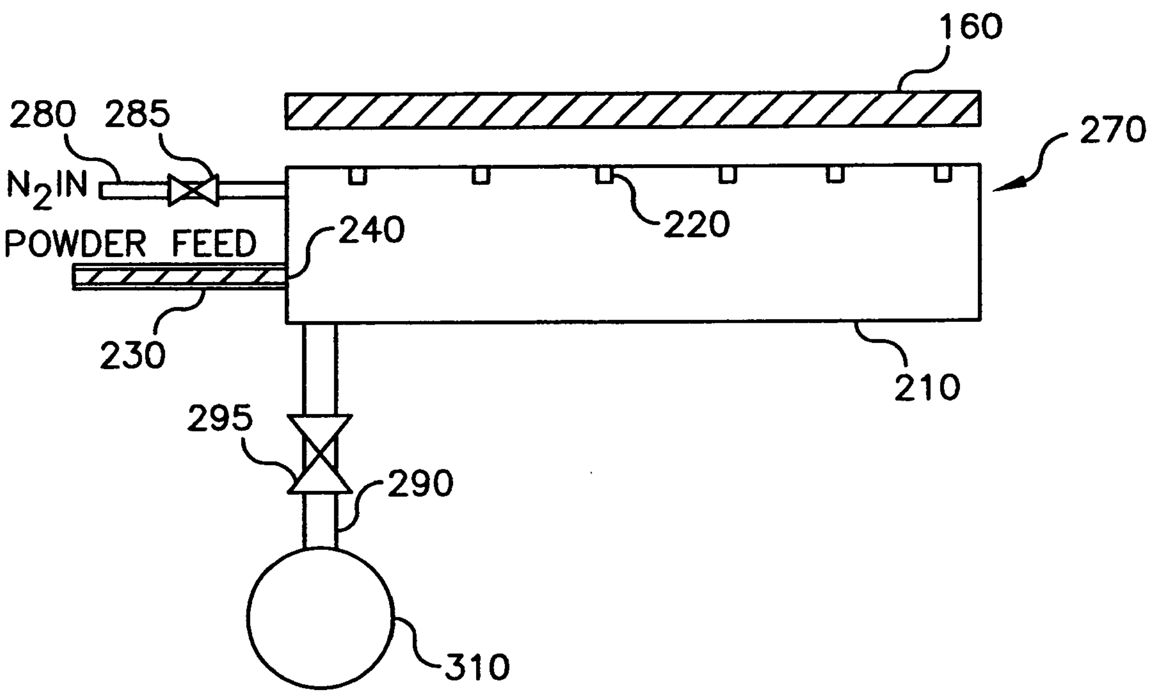


FIG. 4



160
200
260
POWDER
FEED
240
220
250
230
210

FIG. 5



160
280
285
270
N_2IN
220
POWDER FEED
240
230
210
295
290
310

FIG. 6

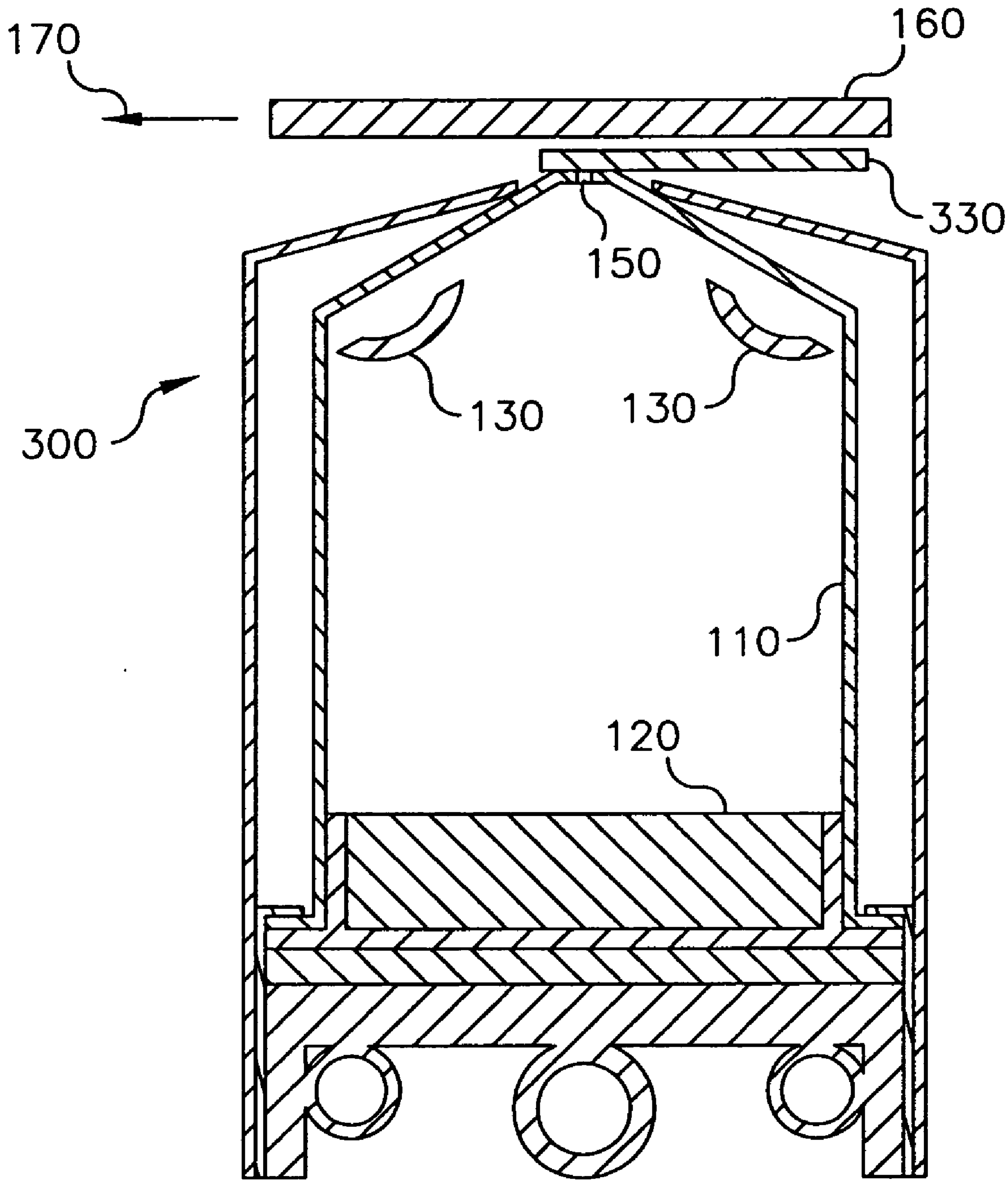


FIG. 7A

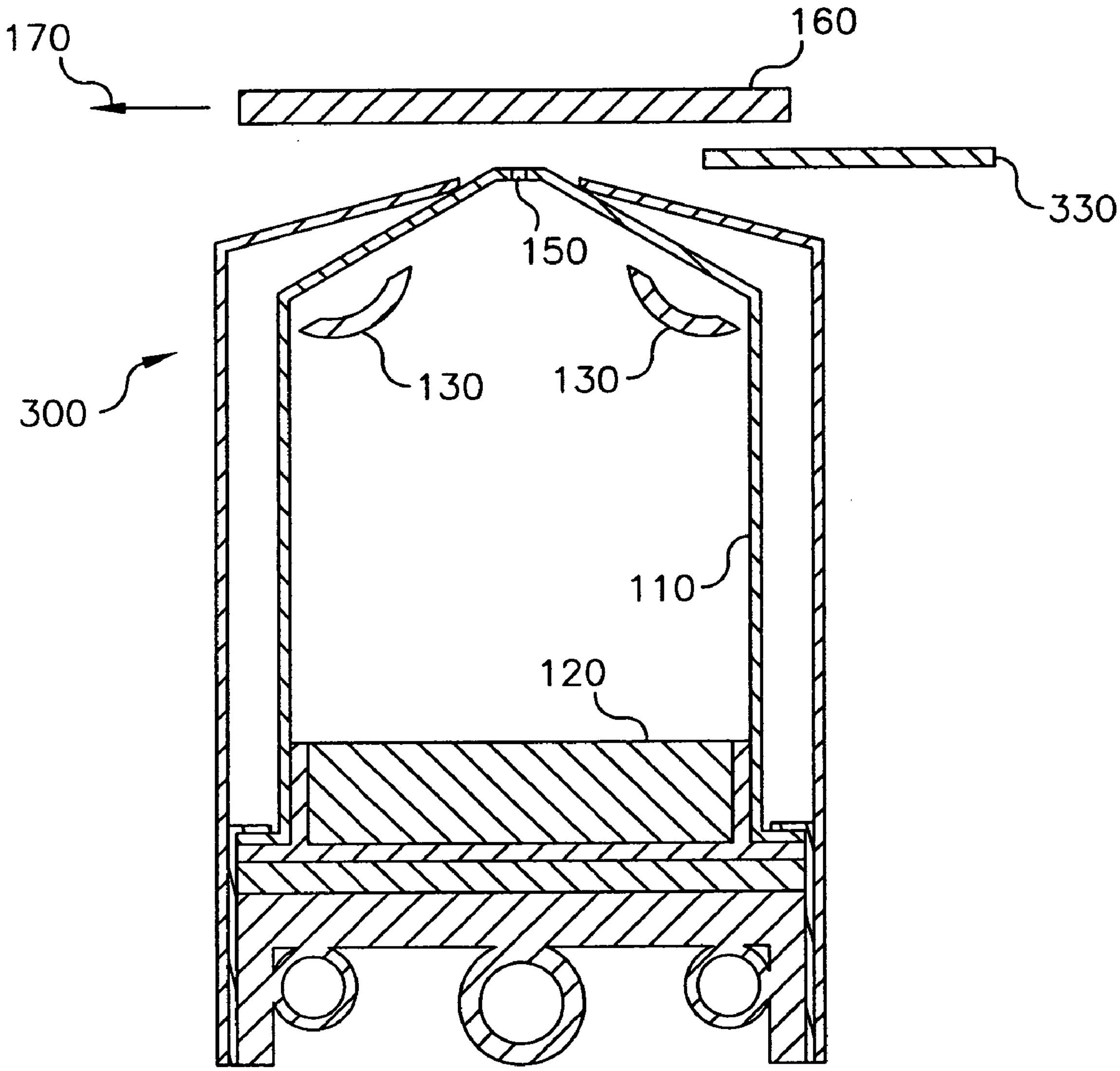


FIG. 7B

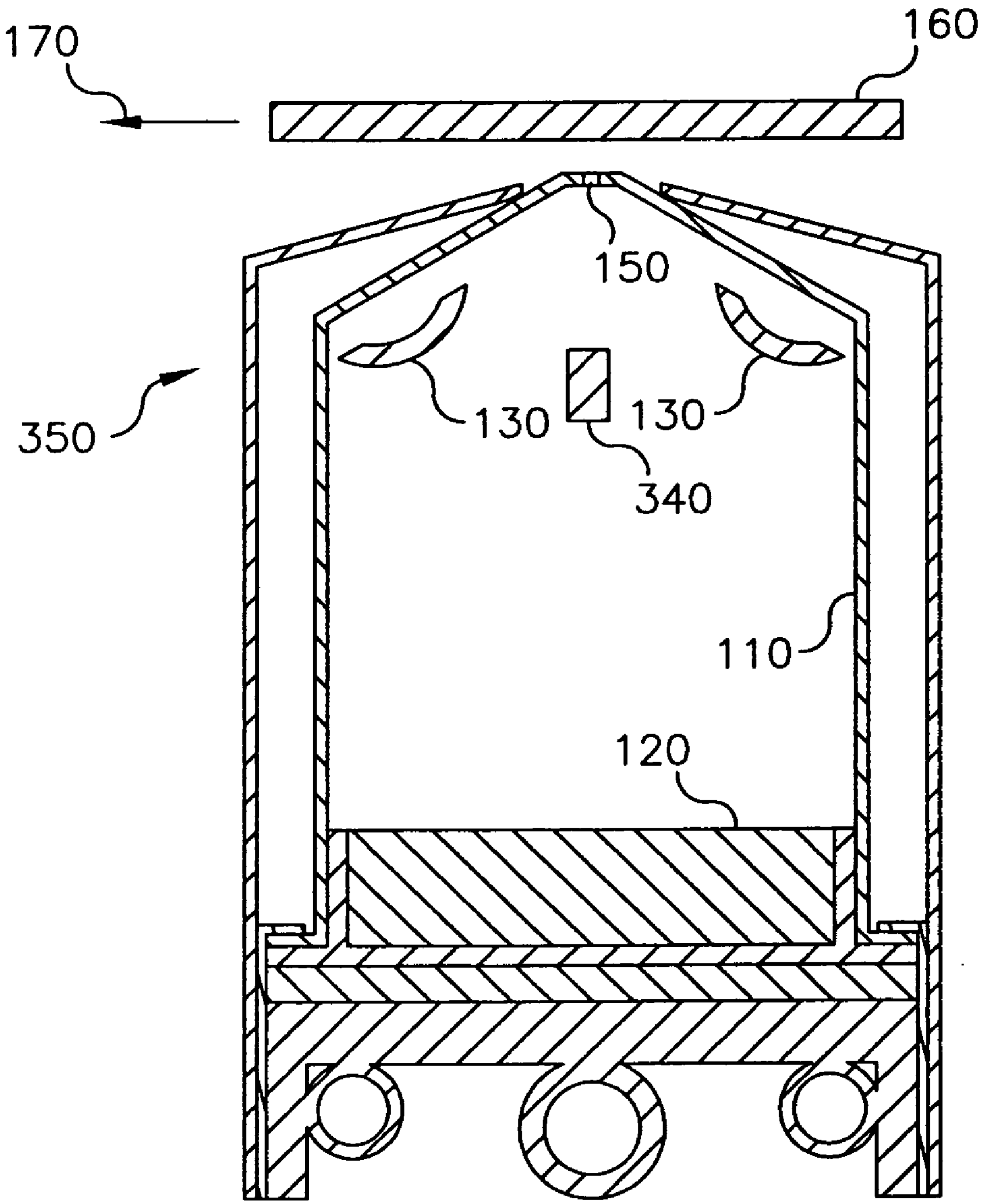


FIG. 8

CONTROLLING THE VAPORIZATION OF ORGANIC MATERIAL

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] Reference is made to commonly assigned U.S. patent application Ser. No. 10/805,847, filed Mar. 22, 2004, entitled "High Thickness Uniformity Vaporization Source" by Long et al, U.S. patent application Ser. No. 10/945,940, filed Sep. 21, 2004, entitled "Delivering Organic Powder to a Vaporization Zone" by Long et al and U.S. patent application Ser. No. 10/______ filed concurrently herewith, entitled "Controlling the Vaporization of Organic Material" by Boroson et al the disclosures of which are incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The present invention relates to the field of physical vapor deposition where a source material is heated to a temperature so as to cause vaporization and create a vapor plume to form a thin film on a surface of a substrate.

BACKGROUND OF THE INVENTION

[0003] Physical vapor deposition in a vacuum environment is a commonly used way of depositing thin organic material films, for example in small molecule OLED devices. Such methods are well known, for example Barr in U.S. Pat. No. 2,447,789 and Tanabe et al. in EP 0 982 411. The organic materials are often subject to degradation when maintained at or near the desired rate-dependent vaporization temperature for extended periods of time. Exposure of sensitive organic materials to higher temperatures can cause changes in the structure of the molecules and associated changes in material properties.

[0004] The organic materials used in OLED devices have a highly non-linear dependence of vaporization rate on source temperature. A small change in source temperature leads to a very large change in vaporization rate. Despite this, prior art devices employ source temperature as the only way to control vaporization rate. To achieve good temperature control, prior art deposition sources typically utilize heating structures whose solid volume is much larger than the organic charge volume, composed of high thermal-conductivity materials that are well insulated. The high thermal conductivity insures good temperature uniformity through the structure and the large thermal mass helps to maintain the temperature within a critically small range by reducing temperature fluctuations. These measures have the desired effect on steady-state vaporization rate stability but have a detrimental effect at start-up. It is common that these devices must operate for long periods of time (e.g. 2-12 hours) at start-up before steady state temperature distribution and hence a steady vaporization rate is achieved. It is also common that these devices also require long times to cool down, and thus significant amounts of organic material, some of which can be expensive or difficult to synthesize, can be lost. Furthermore the steady state slowly drifts as material is consumed from the sources, and input power must be changed (in order to alter the temperature distribution) to maintain a constant vaporization rate.

[0005] The current method to minimize material time at high temperature and to maximize machine operation time by minimizing the start-up and cool-down times of the material-containing sources requires using duplicate sources of the same material sequentially. For example, rather than using one source continuously for eight days, two sources can be used for four days each or eight sources can be used in a serial process for one day each by overlapping the start-up and cool-down times. Duplicate sources, however, increase equipment size and cost, especially if the number of duplicate sources or the number of materials that require duplicate sources is large.

[0006] Forrest et al. (U.S. Pat. No. 6,337,102 B1) disclose a method for vaporizing organic materials and organic precursors and delivering them to a reactor vessel wherein the substrate is situated, and delivery of the vapors generated from solids or liquids is accomplished by use of carrier gases. The organic materials are held at a constant temperature that is high enough to saturate the incoming carrier gas at all possible flow rates. Deposition rate is controlled by adjusting the carrier-gas flow rate. In one embodiment of their invention, Forrest et al. locate the substrates within a suitably large reactor vessel, and the vapors carried thereto mix and react or condense on the substrate. Another embodiment of their invention is directed towards applications involving coating of large area substrates and putting several such deposition processes in serial fashion with one another. For this embodiment, Forrest et al. disclose the use of a gas curtain fed by a gas manifold (defined in the disclosure as "hollow tubes having a line of holes") in order to form a continuous line of depositing material perpendicular to the direction of substrate travel.

[0007] One major problem in the approach disclosed by Forrest et al. is that all of the materials are continuously heated in high thermal mass systems to maintain tight temperature control. This exposure to high temperatures for extended periods of time increases the likelihood of degradation of some materials in the same way as the methods taught by Barr and Tanabe et al. Another problem in the approach disclosed by Forrest et al. is that cool-down and start-up times to reload material are long, due to the high thermal mass of the system and the requirement that all materials be at a uniform temperature before starting the carrier gas flow.

[0008] Also known in the art are systems such as taught by Hoffman et al. of Applied Films GmbH & Co. in their paper from the Society for Information Display 2002 International Symposium, SID Digest 02 pp. 891-893. These systems combine large heated remote sources similar to the type used by Barr and Tanabe et al. with manifolds to distribute the material vapor. These systems suffer from the same problems as the methods taught by Barr, Tanabe et al., and Forrest et al. with respect to material degradation, due to long term exposure to high temperatures and long cool-down and start-up times due to the high thermal mass of the heating system.

[0009] The approaches to vapor delivery as disclosed by Forrest et al. and Hoffman et al. can be characterized as "remote vaporization" wherein a material is converted to vapor in an apparatus external to the deposition zone and more likely external to the deposition chamber. Organic vapors, alone or in combination with carrier gases, are conveyed into the deposition chamber and ultimately to the substrate surface. Great care must be taken using this approach to avoid unwanted condensation in the delivery lines by use of appropriate heating methods. This problem becomes even more critical when contemplating the use of inorganic materials that vaporize to the desired extent at substantially higher temperatures. Furthermore, the delivery of the vaporized material for coating large areas uniformly requires the use of gas manifolds.

[0010] Current remote-vaporization methods suffer from the problems of long material exposure to high temperatures and start-up and cool-down delays due to high thermal mass heating systems; however, these systems have some advantages over the methods taught by Barr and Tanabe et al. with respect to coating uniformity and control of instantaneous deposition rates. Although these remote vaporization methods can stop deposition fairly quickly by closing valves for the carrier gases in the method of Forrest et al. or for the organic vapors in the method of Hoffman et al., the organic vapors and carrier gases downstream of the valves will continue to exit the manifold until the manifold pressure drops to the deposition chamber pressure. Likewise this method can start deposition fairly quickly but organic vapors and carrier gases will not reach steady state deposition rates until the manifold has reached steady state pressure. This is a problem due to remote vaporization combined with structures, such as valves, to control the flow of organic vapors that are also remote from and not contiguous to the manifold. These remote structures do not quickly control the passage of organic material through the manifold apertures, resulting in delays in starting and stopping deposition. Remote vaporization systems with remote valves do not resolve the significant issue of long start-up and cool-down times for loading fresh material, due to the high thermal mass of these systems, nor do they resolve the major issue of material degradation due to extended exposure to high temperature in these systems.

[0011] Furukawa et al., in Japanese Unexamined Patent Application 9-219289, disclose a method of forming an organic thin-film electroluminescent element by a flash vapor deposition method. While this method can start and stop quickly, it cannot be run as a continuous process as taught by Furukawa et al. The organic material is dropped onto a heated plate. Furakawa is silent on the nature of the powder delivery system, and how it assures that the desired quantity of powder is actually dropped on the heated plate, and therefore how vaporization rate, the deposited film thickness, and thickness uniformity are controlled. Also unclear is how the powder delivery system, with a temperature below the condensation temperature of the just-created vapor, is prevented from acting as a cold finger upon which a portion of the just-created vapor condenses.

SUMMARY OF THE INVENTION

[0012] It is therefore an object of the present invention to achieve physical vapor deposition at a steady state with short start and stop times. It is a further object that the vapor deposition can be run continuously and in any orientation. It is a further object to minimize the heat-promoted degradation of organic materials without resorting to large numbers of duplicate sources. It is a further object to minimize the start-up and cool-down times for reloading materials without resorting to duplicate sources.

[0013] This object is achieved by a method for controlling the deposition of vaporized organic material onto a substrate surface, comprising:

[0014] a) providing a manifold having at least one aperture through which vaporized organic material passes for deposition onto the substrate surface; and

[0015] b) providing a volume of organic material and maintaining the temperature of such organic material in a first condition so that its vapor pressure is below that needed to effectively form a layer on the substrate, and in a second condition heating a volume percentage of the initial volume of such organic material so that the vapor pressure of the heated organic material is sufficient to effectively form a layer.

[0016] It is an advantage of the present invention that the deposition of organic material vapors can be started and stopped in a matter of seconds to achieve a steady vaporization rate quickly. This feature minimizes contamination of the deposition chamber walls and conserves the organic materials when a substrate is not being coated.

[0017] It is another advantage of the present invention that the device overcomes the heating and volume limitations of prior art devices in that only a small portion of organic material is heated to the desired rate-dependent vaporization temperature at a controlled rate. It is therefore a feature of the present invention to maintain a steady vaporization rate with a large charge of organic material and with a steady heater temperature. The device permits extended operation of the source with substantially reduced risk of degrading even very temperature-sensitive organic materials. This feature additionally permits materials having different vaporization rates and degradation temperature thresholds to be co-sublimated in the same source. This feature additionally permits short material-reloading times due to the low thermal mass of the heated material.

[0018] It is a further advantage of some embodiments of the present invention that it permits finer rate control and additionally offers an independent measure of the vaporization rate.

[0019] It is a further advantage of some embodiments that the present device achieves substantially higher vaporization rates than in prior art devices without material degradation. Further still, no heater temperature change is required as the source material is consumed.

[0020] It is a further advantage of some embodiments of the present invention that it can provide a vapor source in any orientation, which is not possible with prior-art devices.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] **FIG. 1** shows a cross-sectional view of an apparatus for controlling the vaporization of organic material in a vaporization source onto a substrate surface in accordance with this invention;

[0022] **FIG. 2** shows a cross-sectional view of the above apparatus in a configuration for controlling the vaporization of organic material in accordance with this invention;

[0023] **FIG. 3** shows a cross-sectional view of another apparatus for controlling the vaporization of organic material in a vaporization source onto a substrate surface in accordance with this invention:

[0024] **FIG. 4** shows a cross-sectional view of an apparatus for controlling the deposition of vaporized organic material onto a substrate surface from a vaporization source in accordance with this invention;

[0025] **FIG. 5** shows a schematic view of another apparatus for controlling the deposition of vaporized organic material onto a substrate surface from a vaporization source in accordance with this invention;

[0026] **FIG. 6** shows a schematic view of another apparatus for controlling the deposition of vaporized organic material onto a substrate surface from a vaporization source in accordance with this invention;

[0027] **FIG. 7*a*** shows a cross-sectional view of another apparatus in a closed configuration for controlling the deposition of vaporized organic material onto a substrate surface from a vaporization source in accordance with this invention;

[0028] **FIG. 7*b*** shows a cross-sectional view of the above apparatus in an open configuration; and

[0029] **FIG. 8** shows a cross-sectional view of another apparatus in an open configuration for controlling the deposition of vaporized organic material onto a substrate surface from a vaporization source in accordance with this invention.

DETAILED DESCRIPTION OF THE INVENTION

[0030] Turning now to **FIG. 1**, there is shown a cross-sectional view of an apparatus for controlling the deposition of vaporized organic material onto a substrate surface by controlling the vaporization of organic material in a vaporization source onto a substrate surface in accordance with this invention. Apparatus **10** is a vaporization source and includes an initial volume of organic material **20** and a metering device **60** for advancing organic material **20** in a controlled manner from first temperature-controlled region **30** to second temperature-controlled region **50**. Metering device **60** can be e.g. an auger screw or a similar auger structure. Such metering device, and a way of providing a volume of organic material to them, have previously been described by Long et al. in above-cited commonly assigned U.S. patent application Ser. No. 10/945,940, the disclosure of which is incorporated by reference. First temperature-controlled region **30** can be a region of high thermal mass, e.g. a large base, and can include such materials as metals and ceramics to maintain organic material **20** at a desired temperature below its vaporization temperature. First temperature-controlled region **30** can be heated or cooled as needed and includes a first heating device, which can be any well-known heating device, e.g. heating coil, induction heating, heating/cooling tubes, and the like. The first heating device is not shown for clarity. First temperature-controlled region **30** is heated to and maintained below the vaporization temperature of organic material **20**.

[0031] The vaporization temperature is defined as the lowest temperature wherein the vapor pressure of organic material **20** is sufficient to effectively form a layer of organic material on a substrate. By effectively we mean at a practical manufacturing rate. Because the vapor pressure of a material is a continuous function with respect to temperature, at any non-zero absolute temperature, the material has a non-zero vapor pressure. The above definition of vaporization temperature is useful for describing operating conditions and relative temperatures of various regions within a practical deposition device.

[0032] A related matter is that of the condensation temperature. At a given partial pressure of material, the material vapor will condense onto a surface held at or below a measurable temperature. This temperature is defined as the condensation temperature and depends on the partial pressure of the material vapor.

[0033] Apparatus **10** also provides a manifold, a portion of which is shown by manifold walls **80**. The manifold includes one or more apertures through which the vaporized organic material will pass for deposition onto a substrate surface. Long et al. have discussed examples of suitable manifolds in above cited, commonly assigned U.S. patent application Ser. No. 10/805,847, the disclosure of which is incorporated by reference. The manifold can also consist of a single-aperture heated-wall structure similar to the type commonly referred to as point sources.

[0034] Second temperature-controlled region **50** is the region from the end of first temperature-controlled region **30** to a second heating device **40**. Second heating device **40** can be a heating element that has a very low thermal mass as seen by organic material **20**. Such heating elements include permeable heating elements such as wire mesh screens and reticulated porous structures including fine ligaments, and can be heated by induction, RF energy, or by conducting a current along its length. Second heating device **40** heats organic material **20** above its vaporization temperature in second temperature-controlled region **50**, so that the vapor pressure of the heated organic material is sufficient to effectively form a layer on a substrate and the organic material adjacent to the permeable heating element vaporizes and is released into the manifold. Organic material **20** is metered at a predetermined controlled rate to second temperature-controlled region **50** so that organic material **20** is vaporized by heat at a controlled rate and the vaporized organic material passes through the permeable heating element, that is, second heating device **40**, into the manifold and out through the manifold apertures. In this embodiment the second heating device **40** is shown inside the manifold, but for embodiments where the second heating device **40** is contiguous to the manifold, the second heating device **40** can be outside the manifold as long as the volume of the connection between the second heating device **40** and the manifold is small relative to the internal volume of the manifold. For embodiments where the heating device is distant from the manifold, the volume of the connection is not important as long as the connection is maintained above the condensation temperature of the vaporized organic material.

[0035] In practice, the vaporization of organic material **20** can be controlled by controlling the metering of organic material **20**, or by controlling the temperature applied to organic material **20** at second temperature-controlled region **50**, or both. A controller for controlling the temperature at second temperature-controlled region **50** and reduces a potential and thereby applies a current to second heating device **40**, that reduces the RF energy applied to second heating device **40**, and separates second heating device **40** and organic material **20**. In order to separate second heating device **40** and organic material **20** a mechanical structure is provided for moving second heating device **40** away from organic material **20**, and reversing the metering device that feed organic material **20** to second heating device **40**. In a first condition, the temperature of organic material **20** is maintained below that needed to effectively form a layer on the substrate, that is, below the vaporization temperature. In a second condition, a small volume percentage of the initial volume of organic material **20** adjacent to second heating device **40** (that is, the portion between first temperature-controlled region **30** and second heating device **40**) is heated above the vaporization temperature so that the vapor pressure of the heated organic material is sufficient to effectively form a layer on a substrate placed near the apertures of the manifold. **FIG. 1** is in the second condition when second heating device **40** is heated as described above. Thus, all organic material is contained in a single source while only a small volume percentage (less than 10%) of the initial volume of organic material is heated to the vaporization temperature at any time. This reduces the likelihood of material degradation.

[0036] To rapidly reduce the vaporization of organic material **20**, apparatus **10** is put into the first condition. This can be achieved by decreasing the heat from second heating device **40** (e.g. by reducing a potential applied to it so as to reduce the current through it), or by separating second heating device **40** from organic material **20**, or both. **FIG. 2** shows a cross-sectional view of the above apparatus **10** where heating device **40** has been moved away from organic material **20** so that apparatus **10** is in the first condition and organic material is not being vaporized. Alternatively, heating device **40** can be stationary and organic material **20** can be moved away from the heating device, e.g. by reversing metering device **60**. This can change the vaporization rate from greater than 90% of the maximum rate to less than 10% of the maximum rate in less than 5 minutes, and times less than 3 seconds can be achieved. One can also cool organic material **20**, e.g. by cooling first temperature-controlled region **30**. One can use any combination of these techniques to quickly reduce the vaporization rate of organic material **20**.

[0037] The ability to reduce the vaporization rate quickly is attained by several features of this invention that provide a thermal time constant of the vaporization process on the order of one second. Heating device **40** is thin and thus has a low thermal mass in contact with organic material **20**. Metering device **60** feeds organic material **20** in the shape of a thin cylinder, such that organic material **20** has a small cross-sectional area in second temperature-controlled region **50**, but has a much larger area in contact with first temperature-controlled region **30**, which can act as a heat sink.

[0038] Turning now to **FIG. 3**, there is shown a cross-sectional view of another apparatus for controlling the vaporization of organic material in a vaporization source onto a substrate surface in accordance with this invention, showing an alternative way of applying heat to organic material **20**. Focused radiation **70** is applied onto an exposed surface of organic material **20** and heats a small volume percentage of the initial volume of organic material **20** to vaporization in the second condition of apparatus **10**. Thus, all organic material is contained in a single source while only a small volume percentage (less than 10%) of the initial volume of organic material is heated to the vaporization temperature at any time. This reduces the likelihood of material degradation. Radiation **70** can be applied by a microwave device, an infrared device, or the like. In the first condition, radiation **70** is turned off. Radiation **70** can be turned off or on in a fraction of a second, thus stopping or starting vaporization of organic material **20** in a matter of seconds. Thus this method can rapidly control the application of vaporized organic material onto a substrate surface by rapidly controlling the vaporization of the organic material **20** in the vaporization source.

[0039] Turning now to **FIG. 4**, there is shown a cross-sectional view of an apparatus for controlling the deposition of vaporized organic material onto a substrate surface from a vaporization source in accordance with this invention. Apparatus **100** is a vaporization source that includes manifold **110** for containing a quantity of vaporized organic material. Manifold **110** includes one or more apertures **150** through which the vaporized organic material passes for deposition onto the surface of substrate **160**. Substrate **160** can be moved in direction **170** so as to sequentially coat the entire substrate surface. Apparatus **100** further includes organic material **120** and heating device **130**, for example radiant heaters, to heat a portion of organic material **120** above its vaporization temperature. Although apparatus **100** is shown with a charge of organic material **120**, it can be constructed instead to meter organic material into manifold **10** and heat the metered materials, for example by an auger structure and permeable heating element, as shown in other embodiments of this invention. Thus, all organic material is contained in a single source while only a small volume percentage (less than 10%) of the initial volume of organic material is heated to the vaporization temperature at any time. This reduces the likelihood of material degradation.

[0040] Apparatus **100** further provides hollow member **140** positioned in manifold **110** in the flow path of vaporized organic material. Hollow member **140** is a structure operating independently of heating device **130** and is effective in a first condition for limiting the passage of vaporized organic material through apertures **150**, and effective in a second condition for facilitating the passage of organic material through aperture **150**. The outside surface of hollow member **140** is a temperature-control surface, by which we mean that the temperature of the outside surface of hollow member **140** and thereby its immediate surroundings can be controlled by temperature-controlling material (e.g. refrigerant fluid such as chlorofluorocarbons) that can be delivered at a controlled temperature through the interior of hollow member **140** by a structure for delivering such temperature-controlling material (e.g. a pump or compressor) so as to absorb heat from or deliver heat to hollow member **140**. In a first condition, hollow member **140** is cooled so as to cause the deposition of vaporized organic material onto the surface of hollow member **140** and not onto the surface of substrate **160**. Under these conditions, organic material does not escape apertures **150**, and therefore is not deposited on the surface of substrate **160**. In a second condition, hollow member **140** is held at approximately the same temperature as the bulk of the interior of manifold **110**, and hollow member **140** is effective so as to minimally affect the flow of vaporized organic material to apertures **150** and thereby to the surface of substrate **160**. Additional control can be attained by decreasing the heat from heating device **130** when hollow member **140** is effective in its first condition and increasing the heat from heating device **130** when hollow member **140** is effective in its second condition.

[0041] Turning now to **FIG. 5**, there is shown a schematic view of another apparatus for controlling the deposition of vaporized organic material onto a substrate surface from a vaporization source in accordance with this invention. A quantity of organic material is provided into apparatus **200**, which is a vaporization source. Organic material can be provided by metering device **230**, such as an auger structure as already described. It will be understood that in other embodiments the organic material can also be provided in a bulk charge, of which only a portion is heated to the vaporization temperature at a given time as described above, or vaporized organic material can be provided from heating device distant from the vaporization source. In the latter case, the connection between the vaporization source is maintained above the condensation temperature of the vaporized organic material. In this embodiment heat from heating device **240** is applied to the organic material, for example by using an auger structure to move the organic material to a permeable heated element. Thus, all organic material is contained in a single source while only a small volume percentage (less than 10%) of the initial volume of organic material is heated to the vaporization temperature at any time. This reduces the likelihood of material degradation. The organic material is vaporized by heating device **240** into manifold **210** and thereby out apertures **220**, to be deposited on the surface of substrate **160** placed close to apertures **220** on the outside of manifold **210**. Apparatus **200** is so constructed that the conductance of organic vapors in manifold **210** is rapid while the conductance of organic vapors through apertures **220** is slower. Flow path **260** and valve **250** represent a structure that can be contiguous to or distant from the manifold **210**, that operates independently of heating device **240**, and that is effective in a first condition for limiting the passage of vaporized organic material through apertures **220**, and effective in a second condition for facilitating the passage of organic material through apertures **220**. The flow of vaporized organic material can be rapidly diverted from manifold **210** to a first flow path **260** by opening valve **250**. In the first condition, first flow path **260** is opened by opening valve **250** so that vaporized organic material is not deposited on the surface of substrate **160**. In the second condition, valve **250** is closed so as to allow organic material to be deposited on substrate **160**. The deposition of vaporized organic material on the surface of substrate **160** can be rapidly started and stopped.

[0042] Turning now to **FIG. 6**, there is shown a schematic view of another apparatus for controlling the deposition of vaporized organic material onto a substrate surface from a vaporization source in accordance with this invention. A quantity of organic material is provided into apparatus **270**, which is a vaporization source. Apparatus **270** includes manifold **210** with one or more apertures **220**, a device for heating the organic material either contiguous to or distant from the manifold above the vaporization temperature of the organic material, a reservoir **310**, a structure for defining a flow path **290** connecting reservoir **310** to manifold **210**, and another structure connects flow path **290** to reservoir **310** so that the pressure of vaporized organic material in manifold **210** can be reduced. These will be described in further detail. Organic material can be provided by metering device **230**, such as an auger structure as already described. It will be understood that the organic material can also be provided in a bulk charge, of which only a portion is heated to the vaporization temperature at a given time, as described above. Heat from heating device **240** is applied to the organic material, for example by using an auger structure to move the organic material to a permeable heating element. Thus, all organic material is contained in a single source while only a small volume percentage (less than 10%) of the initial volume of organic material is heated to the vaporization temperature at any time. This reduces the likelihood of material degradation. The organic material is vaporized by heating device **240** into manifold **210** and thereby out apertures **220**, to be deposited on the surface of substrate **160** placed close to apertures **220** on the outside of manifold **210**. Apparatus **270** is so constructed that the conductance of organic vapors in manifold **210** is rapid while the conductance of organic vapors through apertures **220** is slower. Flow path **290**, valve **295**, reservoir **310**, inert gas inlet **280**, and valve **285** represent a structure operating independently of heating device **240** and are effective in a first condition for limiting the passage of vaporized organic material through apertures **220**, and effective in a second condition for facilitating the passage of organic material through apertures **220**. First flow path **290** is provided connected to manifold **210**. Reservoir **310** is provided connectable to first flow path **290** and can serve to store diverted vaporized organic material from manifold **210**, for example by providing a temperature of reservoir **310** below the condensation temperature of the diverted organic material.

[0043] Apparatus **270** also includes an inert gas inlet **280** and a valve **285** for providing a supply of inert gas, e.g. nitrogen, to manifold **210**. The flow of vaporized organic material can be rapidly diverted from manifold **210** to a first flow path **290** by opening valve **295**. In the first condition, first flow path **290** is opened by opening valve **295**, and a supply of inert gas is supplied through inert gas inlet **280** to manifold **210** by opening valve **285**, so that vaporized organic material is delivered to reservoir **310**. This can rapidly sweep the vaporized organic material from the interior of manifold **210**. In the second condition, valves **285** and **295** are closed, closing first flow path **290** to reservoir **310**, so as to allow organic material to be deposited on substrate **160**. The deposition of vaporized organic material on the surface of substrate **160** can be rapidly started and stopped. One advantage of this apparatus is that it is not necessary to turn off heat source **240** to stop the flow of organic material to an external substrate. Thus, when one is ready to restart coating of an external substrate, one can simply close valves **285** and **295** and rapidly refill manifold **210** with organic material vapors.

[0044] Turning now to **FIGS. 7*a*** and **7*b***, there is shown a cross-sectional view of an apparatus for controlling the deposition of vaporized organic materials onto a substrate surface from a vaporization source in accordance with this invention. Apparatus **300** is a vaporization source that includes manifold **110** for containing a quantity of vaporized organic material. Manifold **110** includes one or more apertures **150** through which the vaporized organic material passes for deposition onto the surface of substrate **160**. Substrate **160** can be moved in direction **170** so as to sequentially coat the entire surface of substrate **160**. Apparatus **300** further includes organic material **120** and heating device **130**, for example radiant heaters, to heat a portion of organic material **120** above its vaporization temperature. Although apparatus **300** is shown with a charge of organic material **120**, it can be constructed to meter organic material into manifold **110** and heat the metered materials, for example by an auger structure and permeable heating element, as shown in other embodiments of this invention. Thus, all organic material is contained in a single source while only a small volume percentage (less than 10%) of the initial volume of organic material is heated to the vaporization temperature at any time. This reduces the likelihood of material degradation.

[0045] Vaporization apparatus **300** also includes movable element **330** contiguous to the manifold. Movable element **330** is a structure operating independently of heating device **130** and is effective in a first condition for limiting the passage of vaporized organic material through apertures **150**, and effective in a second condition for facilitating the passage of organic material through apertures **150**. In a first position, shown in **FIG. 7***a*, element **330** limits the flow of vaporized organic material through apertures **150**. Under these conditions, vaporized organic material does not escape apertures **150**, and therefore does not deposit on the surface of substrate **160**. In a second position, shown in **FIG. 7***b*, movable element **330** permits the flow of vaporized organic material through apertures **150** when it is desired to coat substrate **310**. Additional control can be attained by decreasing the heat from heating device **130** when movable element **330** is effective in its first condition and increasing the heat from heating device **130** when movable element **330** is effective in its second condition.

[0046] Turning now to **FIG. 8**, there is shown a cross-sectional view of another apparatus for controlling the deposition of vaporized organic material onto a substrate surface from a vaporization source in accordance with this invention. Apparatus **350** is a vaporization source similar to apparatus **300** above, except that it includes an internal movable element **340** in manifold **110**. Movable element **340** can be moved via mechanics internal to manifold **110** or via a baffle manipulator that is partly outside of manifold **110**. Movable element **340** can be moved into a position wherein it obstructs apertures **150** and thereby blocks the flow of organic materials through the apertures.

[0047] In addition to a single movable element, one can also use a multiplicity of movable elements in a microelectromechanical system (MEMS), wherein each individual aperture **150** has its own movable element to limit the flow of vaporized organic material. Such a MEMS system can include pistons, plungers, bimetallic ribbons, etc.

[0048] It is to be understood that movable elements as shown in these embodiments differ from the use of shutters as practiced in the prior art. Shutters that have been used to prevent the coating of a substrate are used to provide a block to the flow of vaporized organic material to the substrate. However, vaporization of the organic material continues unreduced, material vapor continues to leave the source region (i.e. effuses) and is deposited on the shutter and other surfaces not protected by the shutter. In this invention, the movable elements block the apertures through which the vaporized organic material is released to deposit onto the substrate, and thereby reduce the rate of effusion of material from the source region, while maintaining the operating pressure therein.

[0049] The invention has been described in detail with particular reference to certain preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention.

PARTS LIST

[0050] **10** apparatus

[0051] **20** organic material

[0052] **30** first temperature-controlled region

[0053] **40** heating device

[0054] **50** second temperature-controlled region

[0055] **60** metering device

[0056] **70** radiation

[0057] **80** manifold wall

[0058] **100** apparatus

[0059] **110** manifold

[0060] **120** organic material

[0061] **130** heating device

[0062] **140** hollow member

[0063] **150** aperture

[0064] **160** substrate

[0065] **170** direction

[0066] **200** apparatus

[0067] **210** manifold

[0068] **220** aperture

[0069] **230** metering device

[0070] **240** heating device

[0071] **250** valve

[0072] **260** flow path

[0073] **270** apparatus

[0074] **280** inert gas inlet

[0075] **285** valve

[0076] **290** flow path

[0077] **295** valve

[0078] **300** apparatus

[0079] **310** reservoir

[0080] **330** element

[0081] **340** element

[0082] **350** apparatus

1. A method for controlling the deposition of vaporized organic material onto a substrate surface, comprising:

a) providing a manifold having at least one aperture through which vaporized organic material passes for deposition onto the substrate surface;

b) providing a volume of organic material and maintaining the temperature of such organic material in a first condition so that its vapor pressure is below that needed to effectively vaporize and form a layer on the substrate, and in a second condition heating a volume percentage of the initial volume of such organic material so that the vapor pressure of the heated organic material causes such material to vaporize and pass through the aperture in the manifold to form a layer on the substrate surface; and

c) providing a rotatable auger and metering by using such auger the organic material from the position where such organic material is in the first condition to the position where it is in the second condition to control the rate of vaporization.

2. The method of claim 1 wherein heating the volume percentage of the initial volume of organic material includes applying radiation onto an exposed surface of the organic material.

3. The method of claim 1 further providing a heating device that heats organic material to be in the second condition and stopping the vaporization by separating the heating device from the organic material.

4. The method of claim 1 further including heating the volume percentage of the initial volume by providing a permeable heating element in a temperature-controlled region and using such heated permeable heating element to vaporize organic material adjacent to such permeable heating element so that the vaporized organic material passes through the permeable heating element and into the manifold and out through the manifold aperture.

5. (canceled)

6. Apparatus for controlling the vaporization of organic materials in a vaporization source onto a substrate surface, which comprises:

a) first heating means for heating the organic material in a first temperature-controlled region until it is at a temperature below the vaporization temperature of the organic material;

b) second heating means for heating the organic material above the vaporization temperature in a second temperature-controlled region;

c) means for metering the organic material from the first temperature-controlled region to the second temperature-controlled region, whereby organic material vaporizes and forms on the substrate surface; and

d) means for controlling the temperature applied at the second temperature-controlled region.

7. The apparatus of claim 6 wherein the temperature controlling means includes means for separating the second heating device from the organic material, or means for decreasing the heat provided by the second heating device applied to the organic material, or both.

8. The apparatus of claim 6 wherein the second heating device includes a permeable heating element.

9. The apparatus of claim 6 wherein the second heating device includes means for applying radiation onto a surface of the organic material in the second temperature controlled region.

10. The method of claim 1 wherein during vaporization, less than 10% of the provided volume of organic material is heated to the second condition.

* * * * *