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(54) **EVAPORATOR WITH INTERNAL RESTRICTION**

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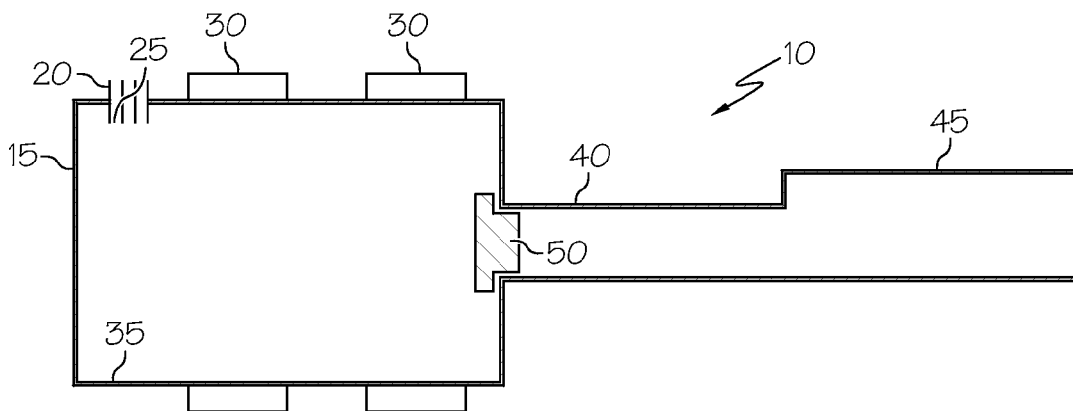
(57) **ABSTRACT**

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An evaporator includes a vaporization chamber having a monomer inlet and a vapor outlet. There is a vapor nozzle in the vapor outlet. The evaporator also includes a collar positioned between the vaporization chamber and the vapor nozzle which increases the pressure in the evaporation chamber while the conductance through the nozzle is substantially unchanged.

**Related U.S. Application Data**

(63) Continuation of application No. 12/650,586, filed on Dec. 31, 2009, now Pat. No. 8,590,338.



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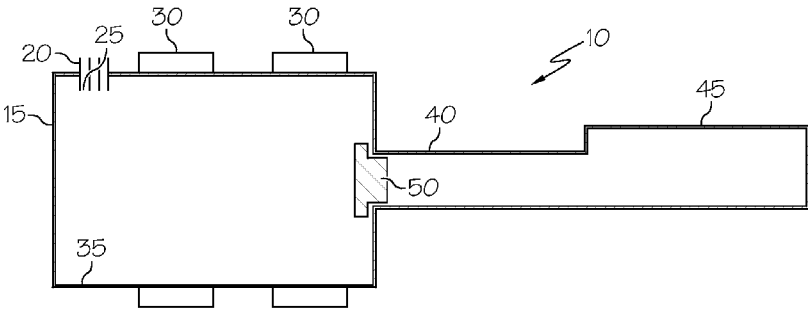


FIG. 1

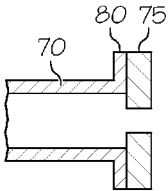


FIG. 2

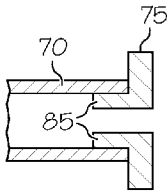


FIG. 3

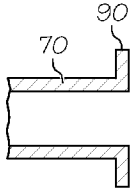


FIG. 4

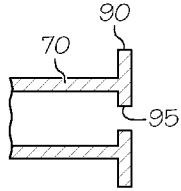


FIG. 5

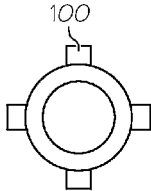


FIG. 6

## EVAPORATOR WITH INTERNAL RESTRICTION

### CROSS-REFERENCE TO RELATED APPLICATIONS

**[0001]** This application is a continuation of co-pending (and now allowed) U.S. patent application Ser. No. 12/650,586, filed Dec. 31, 2009 and entitled "EVAPORATOR WITH INTERNAL RESTRICTION".

**[0002]** The invention relates generally to evaporators for flash evaporation, and more particularly to an evaporator having improved evaporator pressure stability and film uniformity.

### BACKGROUND OF THE INVENTION

**[0003]** Flash evaporation of a liquid (single or multi-component) uses an ultrasonic nozzle to atomize the liquid into small droplets which are then dispersed in a container maintained at elevated temperature (evaporator). When the droplets contact the walls of the evaporator, they instantaneously transform to the vapor state without boiling. This process eliminates the separation or distillation of the individual components of the liquid and maintains the equivalent composition of the liquid in the vapor phase. The flash evaporation process is generally described, for example, in U.S. Pat. Nos. 4,954,371, and 4,842,893, which are incorporated herein by reference.

**[0004]** One problem with this process is that the atomization process is not perfectly constant, which results in fluctuations of the amount of liquid transformed into the vapor phase over time. In one application of the flash evaporation process, the vapor phase is transported to a nozzle where the vapor is directed towards a substrate that passes by the nozzle and onto which the vapor condenses to form a thin liquid layer. Fluctuations in the amount of vapor (as measured by the pressure in the evaporator) result in variation of the flux reaching the substrate, causing an undesirable variation in the thickness of the condensed liquid layer.

**[0005]** One solution to this problem was the introduction of baffles in the evaporator in an attempt to homogenize the vapor pressure before it exits through the nozzle. The use of baffles is described, for example, in U.S. Pat. No. 5,902,641, which is incorporated herein by reference. However, the use of internal baffles has been only partially successful in reducing the vapor fluctuation. Moreover, this method adds complexity and expense to the evaporator fabrication.

**[0006]** In addition, in order for a uniform liquid film to be formed on the substrate, the pressure in the evaporator should reach a steady-state condition in as short a time as possible. This reduces the overall time for the discrete coating process and increases process throughput for manufacture. One method that has been used to reduce the time needed to reach a steady state condition is to narrow the opening of the vapor nozzle through which the vapor exits to the substrate. Although this does reduce the time for the evaporator to reach a steady-state pressure, the machining tolerances of the vapor nozzle become more difficult to achieve, making it more expensive and difficult to fabricate components.

**[0007]** Therefore, there is a need for an evaporator having reduced variation in the amount of vapor reaching the substrate. There is also a need for a less costly evaporator which reaches steady state quickly.

## SUMMARY OF THE INVENTION

**[0008]** The present invention meets this need by providing an improved evaporator. The evaporator includes a vaporization chamber having a monomer inlet and a vapor outlet. There is a vapor nozzle in the vapor outlet. The evaporator also includes a collar positioned between the vaporization chamber and the vapor nozzle. The pressure in the evaporator is increased and the conductance through the nozzle is substantially unchanged. This reduces the impact of any variation in the atomization process.

### BRIEF DESCRIPTION OF THE DRAWINGS

**[0009]** FIG. 1 is a cross-section showing one embodiment of an evaporator.

**[0010]** FIG. 2 is a cross-section of one embodiment of a collar.

**[0011]** FIG. 3 is a cross-section of another embodiment of a collar.

**[0012]** FIG. 4 is a cross-section of another embodiment of a collar.

**[0013]** FIG. 5 is a cross-section of another embodiment of a collar.

**[0014]** FIG. 6 is a cross-section of another embodiment of a collar.

### DETAILED DESCRIPTION OF THE INVENTION

**[0015]** The conductance through the nozzle is an important characteristic in reducing the variation in the amount of vapor reaching the substrate. Conductance is the amount of vapor that can pass through an opening for a given pressure differential. The easiest way to change the conductance is to vary the diameter of the opening. Alternatively, methods using tubes or closely spaced parallel plates can also be used.

**[0016]** In one embodiment, there is a collar located between the evaporation chamber and the vapor nozzle through which the vapor exits onto the substrate. The collar forms a constriction, such as a small aperture, which is designed to match the equivalent restriction that had previously been obtained by narrowing the vapor nozzle exit. The result is that the evaporator pressure is increased while the vapor nozzle exit width remains unchanged. This improves the stability of the evaporator pressure with regard to variations in the atomization process because there is much more vapor contained in the evaporator. Consequently, any fluctuation in the atomization process represents a much smaller fraction of the total vapor. At the same time, the vapor pressure at the vapor nozzle is essentially unchanged because the amount of vapor flowing is the same, and the conductance through the slit of the nozzle is unchanged. The result is that the deposition process (average rate of liquid accumulation on the substrate) is unchanged, and a much more consistent and uniform thin film is deposited. Thus, the collar provides a low cost solution to the problems found in prior art processes.

**[0017]** An additional feature that results from the present invention is that the stabilization of the evaporator pressure allows for the use of feedback to vary the pressure controllably allowing for changes in film thickness in controlled manner. Previously, the fluctuations occurred with a short time period making feedback difficult because of the slow response time of the fluid flow control system. In one implementation of the fluid flow control system, the flow rate is controlled by the rate of displacement of a piston pump containing the fluid. The pump is connected to the atomization

nozzle on the evaporator by a length of tubing. The lag time (delay) of the flow rate to changes in the displacement rate of the pump is similar to the frequency of the fluctuations of the pressure in the evaporator. This makes it difficult to provide a stable feedback system that reduces the pressure fluctuations.

**[0018]** An evaporator **10** is shown in FIG. **1**. There is a vaporization chamber **15** with a fluid inlet **20**. This can be applied to various types of fluid systems, including, but not limited to, monomers, oligomers, resins, and the like, as would be understood by those of skill in the art. There is an atomizer **25**. There are heaters **30** to heat the surface **35** of the vaporization chamber **15**. Monomer flow through the atomizer **25** is atomized into particles or droplets which strike the heated surface **35** whereupon the particles or droplets are flash evaporated into a gas, evaporate, or composite vapor. The gas flows through the vapor outlet **40** and out of the vapor nozzle **45** to the surface being coated where it condenses.

**[0019]** The cross-sectional area of the vapor outlet is less than the cross-sectional area of the vaporization chamber, and the vapor nozzle has a cross-sectional area less than the cross-sectional area of the vapor outlet.

**[0020]** There is a collar **50** between the vaporization chamber **15** and the vapor nozzle **45**. The collar has a cross-sectional area less than the cross-sectional area of the vapor nozzle. The removable collar can be easily inserted into and removed from the vapor outlet. Thus, the amount of vapor which flows out the vaporization chamber is reduced without having to reduce the size of the vapor nozzle.

**[0021]** The collar can be removable, i.e., not permanently attached to the evaporator or the vapor outlet, if desired. For example, it can be inserted in and removed from the vapor outlet. Typically, the collar will simply slide into the vapor outlet and be held by friction. However, other arrangements are possible. Alternatively, the collar can be permanently attached if the size of the aperture does not need to be changed.

**[0022]** Currently, one of the formulation criteria for monomer blends is the evaporation rate and deposition rate using an existing evaporator configuration. The use of the removable collar allows the evaporator configuration to be changed simply by changing the removable collar. This expands the range of blends which can be used to include blends which do not deposit well using the existing configuration. If a particular blend of monomer had less consistent atomization, perhaps as a result of higher viscosity, the hole size of the collar could be reduced to increase the pressure (amount of vapor) in the evaporator to average the fluctuations in atomization over a greater time.

**[0023]** Various embodiments of the removable collar are shown in FIGS. **2-6**. As shown in FIG. **2**, the collar has a first portion **70** which is inserted into the vapor outlet and a second portion **75**. The first portion **70** has an outwardly extending portion **80** which prevents further insertion into the vapor outlet. The outwardly extending portion can be used to grip the collar when it is to be removed. In addition, the second portion of the collar can be connected to the outwardly extending portion, if desired. In this embodiment, the outwardly extending portion is a flange. Alternatively, one or more tabs could be used instead of a flange.

**[0024]** The second portion **75** of the collar has a cross-sectional area less than the cross-sectional area of the vapor outlet. There can be a series of second portions having different sized openings which can be used with the same first portion, for example.

**[0025]** The first portion of the collar can be an annular ring with an annular flange. The second portion can be a second annular flange with a smaller cross-sectional area than the vapor outlet.

**[0026]** The first and second portions can be connected permanently, or they can be removably connected. A removable connection allows the same first portion to be used with more than one second portion. Removable connections include, but are not limited to, screws, threaded helical surfaces, lugs and grooves, tapered connections, bayonet connections, and snap connections. Permanent connections include, but are not limited to, welding. With a permanent connection, the entire collar would be changed, rather than just the second portion.

**[0027]** FIG. **3** shows another embodiment of the collar. The second portion **75** includes a portion **85** which can be inserted into the first portion **70** of the collar. The first and second portions **70, 75** can be held together using a friction fit, or other method as desired. This arrangement allows the cross-sectional area of the collar to be changed by inserting different sized second portions having different cross-sectional areas (e.g., having different wall thicknesses). In this case, the first and second portions are removably connected, as discussed above. There is no flange in this embodiment as shown. However, a flange could be included if desired.

**[0028]** FIG. **4** shows an embodiment of the collar in which there is no second portion. The first portion **70** can be inserted in the vapor outlet. There is an outwardly extending portion **90** which prevents further insertion into the vapor outlet. Suitable outwardly extending portions include, but are not limited to, flanges, and one or more tabs. In this embodiment, the first portion has thicker walls which reduce the cross-sectional area of the collar. In this case, multiple collars would be needed, each with a different cross-sectional area.

**[0029]** In FIG. **5**, the outwardly extending portion **90** also has an inwardly extending portion **95**, which reduces the cross-sectional area. The outwardly and inwardly extending portions **90, 95** can be a flange, if desired. For example, the collar can be an annular ring with an annular flange extending outward from the ring and inward from the ring.

**[0030]** FIG. **6** shows a collar with tabs **100** to prevent further insertion. There is at least one tab, and there can be at least two tabs, or at least three tabs, or at least four tabs, or more. The tabs can be smaller when there are more of them, if desired. Multiple tabs help to prevent the collar from tilting and jamming when being inserted or removed.

**[0031]** The collar can be any desired shape, including, but not limited to cylindrical, square, rectangular, triangular, or other polygonal shape. It will generally be the same shape as the vapor outlet, although it could be a different shape, if desired. The collar will typically be cylindrical.

**[0032]** The collar can be a unitary piece or it can be two or more pieces. If the collar is in two (or more) pieces (e.g., as shown in FIGS. **2-3**), then there can be multiple second portions having different cross-sectional areas. If the collar is a unitary piece (e.g., as shown in FIGS. **4-5**), then multiple collars will be needed to provide a range of cross-sectional areas.

**[0033]** While certain representative embodiments and details have been shown for purposes of illustrating the invention, it will be apparent to those skilled in the art that various changes in the compositions and methods disclosed herein may be made without departing from the scope of the invention, which is defined in the appended claims.

What is claimed is:

**1.** A method of flash evaporating a liquid, the method comprising:

introducing the liquid into an inlet of a vaporization chamber;

passing the liquid through an atomizer that is configured to ultrasonically vaporize the introduced liquid; and

passing the vaporized liquid through a vapor nozzle that is fluidly cooperative with a vapor outlet of the vaporization chamber, where a collar is placed in fluid communication with the vaporization chamber such that an outwardly extending first portion of the collar forms a non-filtered single opening with a substantially unobstructed vapor flowpath therethrough such that upon the passage of the vaporized liquid through the collar, it increases a pressure in the vaporization chamber while leaving the conductance of the vapor through the vapor nozzle substantially unchanged.

**2.** The method of claim **1**, wherein the collar forms an annular ring with an annular flange.

**3.** The method of claim **2**, wherein the outwardly extending first portion further comprises an inwardly extending portion such that the cross-sectional area defining the non-filtered single opening is reduced.

**4.** The method of claim **3**, wherein the inwardly extending portion comprises a flange.

**5.** The method of claim **3**, wherein the inwardly and outwardly extending flanges comprise a single flange.

**6.** The method of claim **2**, wherein the collar further comprises a second portion placed adjacent the first portion, the second portion comprising a second annular flange that defines a smaller cross-sectional area than the non-filtered single opening.

**7.** The method of claim **2**, wherein the collar further comprises a second portion placed adjacent the first portion, the second portion comprising a second annular flange that defines a smaller cross-sectional area than the vapor outlet.

**8.** The method of claim **7**, wherein at least one of the flanges extends outward from the collar.

**9.** The method of claim **7**, wherein at least one of the flanges extends inward from the collar.

**10.** The method of claim **7**, wherein at least one of the flanges extends both inward and outward from the collar.

**11.** The method of claim **7**, wherein the first and second portions are permanently connected to one another.

**12.** The method of claim **7**, wherein the first and second portions are removably connected to one another.

**13.** The method of claim **7**, wherein the second annular flange has the cross-sectional area less than the cross-sectional area of the vapor nozzle.

**14.** The method of claim **1**, further comprising accumulating material on a substrate placed in fluid communication with the vapor nozzle to permit the average rate of material accumulation to remain substantially unchanged.

**15.** A method of flash evaporating a liquid, the method comprising:

introducing the liquid into an inlet of a vaporization chamber that also has a vapor outlet;

passing the liquid through an atomizer that is configured to ultrasonically vaporize the introduced liquid; and

passing the vaporized liquid through a vapor nozzle that is fluidly cooperative with the vapor outlet, where a fluid passageway formed at least in part by a collar placed in fluid communication with the vapor outlet and vapor nozzle is defined by an outwardly extending first portion comprising an annular ring with an annular flange, the fluid passageway forming a substantially unobstructed vapor flowpath such that upon the passage of the vaporized liquid through the collar, it increases a pressure in the vaporization chamber while leaving the conductance of the vapor through the vapor nozzle substantially unchanged.

**16.** The method of claim **15**, further comprising accumulating a material on a substrate that is placed in fluid communication with the vaporization chamber.

**17.** The method of claim **15**, wherein the collar further comprises a second portion placed adjacent the first portion, the second portion comprising a second annular flange.

**18.** The method of claim **17**, wherein at least one of the first and second portions extend inwardly to at least partially define the fluid passageway.

**19.** A method of depositing a flash evaporated liquid, the method comprising:

introducing the liquid into an inlet of a vaporization chamber that also has a vapor outlet;

passing the liquid through an atomizer that is configured to ultrasonically vaporize the introduced liquid;

passing the vaporized liquid through a vapor nozzle that is fluidly cooperative with the vapor outlet, where a collar is placed in fluid communication with the vapor outlet and vapor nozzle such that the collar comprises an outwardly extending first portion comprising an annular ring with an annular flange, and a non-filtered single opening with a substantially unobstructed vapor flowpath therethrough such that upon the passage of the vaporized liquid through the collar, it increases a pressure in the vaporization chamber while leaving the conductance of the vapor through the vapor nozzle substantially unchanged; and

accumulating material on a substrate that is placed in fluid communication with the vapor nozzle.

**20.** The method of claim **19**, the vaporization chamber and collar are configured such that an average rate of material accumulation on the substrate remains substantially unchanged relative to no collar being present.

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