1.1 Cross Reference to Related U.S. Patent Applications

[0001] The present application claims priority to U.S. Provisional Patent Application Serial No. 61/208875 filed 02/27/2009, which is incorporated herein by reference in its entirety and for all purposes.

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1.3 Background of the Invention

1.4 Field of the Invention

[0003] The exemplary, illustrative, technology herein relates to atomic layer deposition (ALD) systems and operating methods thereof and to gas deposition chamber and subsystem configurations that are compatible with robotic large substrate loading and unloading, with autonomous ALD coating operations, and with generating desired gas flow patterns over large rectangular substrates as well as extending the operating time between maintenance procedures so as to enhance production rates.

[0004] The technology herein has applications in the areas of producing single or multiple material monolayer coatings such as those useful for constructing Liquid Crystal Display (LCD) devices.

1.5 The Related Art

[0005] Gas, or vapor, deposition is a method for creating thin material layers (coating) on surfaces that involves exposing a solid substrate surface to a gas or vapor,

walls. Such a liner can be removed from the chamber, cleaned by an acid etch or the like, and then reinstalled into the chamber. One such removable liner is disclosed in co-pending and commonly assigned U.S. Provisional Patent Application No. 61/197,948 filed on November 1, 2008 entitled GAS DEPOSITION CHAMBER WITH REMOVABLE LINER which is incorporated herein by reference in its entirety and for all purposes.

[0012] A further problem with advancing ALD coating systems to commercially viable operation is the need to reduce coating cycle time and this includes the time required to load and unload a substrate, to heat the chamber and substrate to the deposition temperature, to pump the chamber to deep vacuum, to purge contaminants from the chamber, to expose the substrate to precursor gases and to flush the precursor gases out of the chamber. Applicants have found that cycle time can be reduced when the substrate is exposed to a laminar gas flow substantially over its entire coating surface and that this can be accomplished by controlling the velocity and path of input gasses by careful design of an input plenum that distributes the gas over the width of a substrate and reduces the gas velocity.

[0013] A further problem with advancing ALD coating systems to commercially viable operation is the need to fit ALD coating systems into existing production facilities where floor space is at premium. Accordingly, there is a need in the art for an ALD production coating device that provides high coating throughput in a small floor space footprint.

1.6 Summary of the Invention

[0014] These and other problems are addressed by the present invention, which provides a gas deposition system *(1000)* configured as a dual-chamber "tower", including a frame *(1140)* for supporting two reaction chamber assemblies *(3000)*, one vertically above the other. The present invention further provides a gas deposition chamber *(3000)* and associated gas control systems configured to deposit thin film

plate is lowered to a down position the pin tops are lowered below the substrate support surface *(3350)* and the substrate is lowered into contact with the substrate support surface *(3350)*.

[0021] In some embodiment of the present invention the two chamber assemblies may be driven by one gas supply module and evacuated by one vacuum pump and the system controller includes program steps suitable for performing substantially simultaneous coating cycles in both chambers.

[0022] In some embodiments a precursor trap *(10140)* may be disposed in the exit port module (*3320*). In further embodiments one or more additional trap elements may be disposed between the exit port and the vacuum pump.

[0023] These and other aspects and advantages will become apparent when the Description below is read in conjunction with the accompanying Drawings.

1.7 Brief Description of the several views of the Drawings

[0024] Figure 1 depicts an isometric view showing a dual chamber gas deposition system without external skins according to the present invention.

[0025] Figure 2 depicts a plan view of an automated production facility that includes one or more dual chamber gas deposition systems of the present invention.

[0026] Figure 3 depicts a front isometric front view of a gas deposition chamber assembly according to the invention:

[0027] Figure 4 depicts a back isometric back view of a gas deposition chamber assembly according to the invention:

[0028] Figure 5 depicts an isometric view of showing section A-A taken through a gas deposition chamber assembly according to the invention.

[0029] Figure 6 depicts an isometric view of a welded chamber liner assembly according to the present invention.

[0030] Figure 7 depicts schematic representation of an exploded section view showing a substrate supported on the chamber liner assembly and a pair of plenum liners according to the present invention.

[0031] Figure 8 depicts a side view of the top of a lift pin according to the present invention.

[0032] Figure 9 depicts a top schematic view of a double wide gas deposition chamber according to the present invention.

[0033] Figure 10 depicts a front schematic view of dual chamber system having a gas supply module connected to both chambers and a vacuum pump connected to both chambers according to the present invention.

[0034] Figure 11 depicts a front schematic view of a dual chamber system with an input plenum associated with one chamber an output plenum associated with the outer chamber and a rectangular conduit connecting the two chambers together in series according to the present invention.

[0035] Figure 12 depicts an isometric view of a rectangular fluid conduit according to the present invention.

[0036] Figure 13 depicts first and second traps disposed in series between an output plenum and a vacuum pump wherein a stop valve is positioned between the second trap and the vacuum pump according to the present invention.

[0037] Figure 14 depicts first and second traps disposed in series between an output plenum and a vacuum pump wherein a stop valve is positioned between the first and the second trap according to the present invention

[0038] Figure 15 depicts first second trap disposed in parallel fluid conduits extending from an output plenum and a vacuum pump wherein each parallel fluid conduit includes a stop valve and one or more additional traps according to the present invention.

3440 Guide rods	12020 Lower flange/port
3450 Stiffening Fins	12030 Rectangular fluid conduit

13010 Output plenum	
13020 Exit plenum	
13030 1st Precursor trap	
13040 Auxiliary precursor trap	
13050 Stop valve	
13060 Second Trap	
13070 T-fitting	
13080 Stop valve	
13090 Stop valve	
13120 Left conduit	
13130 Right conduit	
13140 Auxiliary precursor trap	
13150 Auxiliary precursor trap	
13160 Second Trap	

1.8 Detailed description of the invention

Frame control system gas supply system and Figure 1

[0041] Referring to Figure 1, a preferred exemplary implementation of a dual chamber gas deposition system *(1000)* according to the present invention is shown in isometric view with the external skins removed. The system (*1000)* includes a front face (*1180*) which is used for loading substrates into each of two gas deposition chambers *(1120)* and *(1150)*. A right side face *(1130)* includes a single user interface device *(1200)* which can be used to enter commands for operating both of the gas deposition chambers *(1120)* and *(1150)*. In alternate embodiments, each gas deposition chamber may include a separate user interface device *(1200)*. In

further alternate embodiments, the control systems of both gas deposition chambers can be networked to a remote device that includes a remote user interface, not shown. The system *(1000)* comprises a frame (*1140*) constructed to support an upper ALD reaction chamber (*1120*) supported by an upper cross frame platform *(1145)* and a lower ALD reaction chamber *(1150)* supported by a lower cross frame platform *(1155)*. Each of the chambers *(1120)* and *(1150)* is constructed to receive a single large area rectangular substrate therein and to support the substrate in a substantially horizontal plane. In particular, the preferred substrate size is a GEN 4.5 glass substrate which has rectangular dimensions of 920 mm wide by 730 mm deep and the chambers *(1120)* and *(1150)* are configured with a front opening or load port having a width dimension along an x-axis that is larger than 730 mm for receiving the substrate width dimension through the front port. Accordingly, the longitudinal length of the chamber along a Y-axis, defined in Figure 3, is greater than 920 mm to receive the GEN 4.5 substrate therein. Alternately, the chamber assembly can be configured to receive substrates in another orientation. Each substrate comprises a top face, to be coated, and an opposing bottom face that is not coated. The substrates have an approximate thickness of 0.5 mm, and are therefore fragile and difficult to handle. The glass substrates are used to manufacture rectangular LCD screens and the like. The chamber includes a horizontal substrate support surface for receiving a bottom face of a substrate thereon with an opposing top face of the substrate top face facing upward. Generally one GEN 4.5 substrate is loaded into a chamber at a time for coating; however, a plurality of smaller glass substrates can be loaded into a chamber *(1120)* or *(1150)* and coated simultaneously. In other embodiments, chamber assemblies for supporting larger or smaller rectangular substrates can be configured. A small chamber assembly may be configured to support a single GEN 1.0 (300 x 400 mm) substrate and a large chamber assembly may be configured to support a single GEN 7.0 (2160x2460 mm) substrate without deviating from the present invention.

[0048] The robotic substrate handler *(2010)* moves the robotic base *(2030)* and the manipulator arm *(2040)* to guide the lifting elements *(2050)* through various wall ports *(2080)* to either pick up or drop off a substrate in a desired area. For example, to pick up an uncoated substrate from a storage rack *(2020)* the lifting elements *(2050)* are extended into the storage rack just below a horizontally supported substrate and then raised to lift and support the substrate on the lifting elements *(2050)*. The robotic substrate handler *(2010)* then withdraws the substrate from the storage rack *(2020)* and transports the substrate to a selected chamber of one of the dual chamber gas deposition systems *(1000)* for insertion into the selected chamber through one of the top or bottom load ports *(1190)* or *(1170)*. The selected chamber may comprise whichever chamber is ready to receive a new substrate for coating, because each chamber of the dual chamber systems *(1000)* communicates with the robotic substrate handler *(2010)* to request loading or unloading of a substrate or to open or close the load lock as required for loading and unloading. Accordingly, in the preferred embodiment of the present invention, the dual chamber tower *(1000)* is configured for autonomous loading and unloading by a robotic substrate handler like the handler *(2010)* shown in Figure 2.

Chamber outer walls, eye hooks, heating elements and insulation Figures 3

[0049] Referring now to Figures 3-8 and 16, a gas deposition chamber assembly *(3000)* is shown in various views with like elements having the same reference number. The chamber *(3000)* is shown in front isometric view in Figure 3, in rear isometric view in Figure 4 and in section view with the section A-A being shown in Figure 5. As best viewed in the schematic view of Figures 5 and 5A, the chamber assembly *(3000)* comprises a plurality of outer walls formed by opposing top and bottom rectangular outer walls *(3010)* and *(3020)* attached to opposing left and right rectangular outer walls *(3030)* and *(3040)* and attached to opposing front and back outer walls *(3042)* and *(3044)* In one embodiment, each of the front and back outer walls *(3042)* and *(3044)* comprise a perimeter flange surrounding a rectangular aperture. A front rectangular aperture *(3035)* passes through the front outer wall *(3010)* and serves as a load port. A back rectangular aperture *(3045)*, which is

external surfaces thereof or disposed as internal layers thereof for preventing thermal heat loss from the chamber assembly. The top outer wall *(3010)* includes a plurality of eye bolts *(3125)* suitable for lifting the chamber assembly *(3000)* into and out of the frame *(1140)* with an overhead hoist or the like.

[0051] Referring to Figures 3, 4 and 5A the reaction chamber assembly *(3000)* has rectangular cross-section in a substantially horizontal X-Y plane with a longitudinal length extending along the y-axis and a transverse width extending along the x-axis with a triangular input plenum *(3150)* attached to the right outer wall *(3040)*, a triangular output plenum attached to the left outer wall *(3030)* and an load port and associated access door disposed at a front wall of the reaction chamber assembly. In other embodiments, the longitudinal length may extend along the x-axis with the transverse width extending along the y-axis without deviating from the present invention. Additionally, the reaction chamber assembly has a height along a z-axis. Similarly, as shown in outer wall assembly of Figure 5A the hollow volume has a rectangular cross-section in an X-Y plane with a longitudinal length extending along the y-axis and a transverse width extending along the x-axis and a height along the z-axis. In the present example, rectangular substrates are loaded into the hollow volume and supported therein on one or more horizontally disposed substrate support surfaces with a longitudinal length of the substrate extending along the y-axis and a transverse width of the substrate extending along the x-axis.

Input and output plenums Figures 3-5

[0052] Referring now to Figures 3 and 5, the right outer wall *(3040)* extends along the Y-axis and is formed with a right rectangular through aperture *(3130)* open to the hollow rectangular chamber *(3070)*. The right rectangular through aperture is substantially centered in the right side wall its position and Y-axis dimension substantially corresponds with the Y-axis position and dimension of a substrate positioned inside the hollow rectangular chamber *(3070)* for coating. An input plenum *(3150)* is attached to the right outer wall *(3040)* by an input plenum flange

substrate support surface *(7010)* such that a substrate supported on the pin tops is placed in contact with the substrate support surface *(7010)*. Preferably the lift pins *(7120)* remain engaged with the through holes *(7110)* when the pins are lower to limit the flow of purge gas through the holes *(7110)* however the pins can be lowered to a position below the bottom liner wall (6010) as shown in Figure 7.

[0068] Referring now to Figure 8, an exemplary embodiment of a lift pin (8000) is shown in cutaway side view. The exemplary lift pin *(8000)* comprises a cylindrical metal shaft *(8010)* and a tip attachment *(8020)*. The tip attachment comprises VESPEL®, a polymer made by DuPont, or another suitable polymer, and is attached to the metal shaft *(8010)* by bonding or other suitable fastening means. Ideally the tip attachment *(8020)* material is can withstand the temperature range and harsh chemical environment of the gas deposition chamber without damage while also providing low out gassing and high thermal and electrical insulation. The top end of the tip attachment *(8020)* is formed with a spherical end (*8030*).

[0069] Referring now to Figure 5, a pin actuator assembly (*3390*) is disposed outside the chamber assembly attached to an external surface of the bottom outer wall *(3020)*. A lift post *(3400)* extends between a pneumatic cylinder and piston assembly *(3410)* and the movable pin plate *(7130)* by passing through a circular hole *(3430)* through the chamber bottom outer wall *(3020)* a vacuum bellows *(3420)*. The vacuum bellows *(3420)* extends from the pneumatic cylinder and piston assembly *(3410)* to the chamber bottom outer wall and vacuum seals the circular through hole *(3430)*. The pin actuator assembly *(3390)* further includes a pair of guide rods *(3440)* for guiding movement of the pneumatic cylinder and piston assembly *(3410)* and the lift post *(3400)*. The system controller coordinates actuation of the pin actuator assembly to raise and lower the movable pin plate when the access door is open for the loading and unloading of substrates.

[0070] Referring to Figures 5 and 7, according to the present invention, a substrate to be coated is installed into the hollow rectangular chamber *(3070)* by lowering the movable access door *(3080)* and raising the movable pin plate *(7130)*. A substrate

(7000) is then inserted into the chamber by the robotic substrate handler *(2010)* or another insertion device and set down resting on the tops of the plurality of lift pins *(7120)*. One dimension of the substrate *(7000)* is substantially centered between the input and output plenums *(3150)* and *(3250)* and the other dimension of the substrate is centered with respect to the left and right rectangular apertures *(3130)* and *(3140)*. The movable pin plate *(7130)* is then lowered to set the substrate *(7000)* onto the substrate support surface *(7110)* and the access door *(3080)* is closed and vacuum sealed. The chamber is then heated to raise the substrate to the gas deposition temperature and the vacuum pump is started to pump the chamber down to a vacuum pressure. The chamber may also be purged with an inert gas during the initial pump down to remove contaminants such as water vapor. When the chamber is at the desired vacuum pressure and the substrate at the desired temperature, a gas deposition recipe can begin. Generally, the recipe begins by closing the stop valve *(3330)* and introducing a precursor gas into the chamber through the input port *(3230)*. Alternately, the precursor can be introduced with the stop valve *(3330)* open and the vacuum pump operating. After the first precursor cycle, the chamber is purged by running the vacuum pump and flushing the chamber with a purge gas. The cycle is then repeated for a second precursor gas and the two precursor gas cycle may be repeated many thousands of times. When substrate coating is complete, the stop valve *(3330)* is closed and the chamber is purged to atmosphere through the input port or another port. The movable access door *(3080)* is opened and the movable pin plate *(7130)* is raised to lift the coated substrate from the substrate support surface. The robotic substrate handler *(2010)* then removes the coated substrate form the chamber and installs an uncoated substrate into the chamber for the next coating cycle.

[0071] Referring now to Figures 9 -11 additional embodiments of the present invention relate to systems and methods for coating two or more substrates in a single chamber assembly, as is shown in Figure 9, or for driving two or more coating chamber assemblies with a single gas supply module and vacuum pump. In particular, Figure 9 depicts a top schematic view of double wide chamber assembly

(9000) configured to receive two rectangular glass substrates *(9010)* and *(9020)* disposed side by side on a horizontal support surface and with a double wide movable door *(9030)* supported for vertical movement to provide access through a front face of the chamber assembly to insert the two rectangular glass substrates *(9010)* and *(9020)*. Otherwise the chamber assembly *(9000)* is substantially identical with the chamber assembly *(3000)* described above. In particular the chamber assembly *(9000)* utilizes the same input plenum *(3150)* disposed between one of the left and right plenum apertures and a gas supply module *(3240)* for delivering gas and vapor phase materials into the outer volume through the corresponding left or right plenum aperture supply module *(3240)* and the same output plenum *(3250)* and exit port module *(3220)* described above. Accordingly, the input plenum delivers a substantially laminar gas flow across the horizontal top surfaces of both of the rectangular glass substrates *(9010)* and *(9020)* before gas is removed from the double wide chamber through the exit port module *(3220)*. In addition, a system controller used to control coating sequences in the chamber assembly *(9000)* may include coating recipes that are adjusted to deliver additional precursor gas volume into the double wide chamber as may be required to ensure that both substrates are uniformly coated.

[0072] Referring now to Figures 10 and 11, two additional embodiments of the present invention are shown schematically. In Figure 10 a dual chamber system *(10000)* includes two chamber assemblies *(10010)* and *(10020)* that are each substantially identical to the chamber assembly *(3000)* described above except that the two chamber assemblies *(10010)* and *(10020)* share a common gas supply module *(10030)* and a common vacuum pump, not shown. Moreover, the two chamber assemblies *(10010)* and *(10020)* may be mounted in the frame *(1140)*, described above and shown in Figure 1, such that the system *(10000)* can replace a dual tower system *(1000)* in the automated production facility *(2000)* described above and shown in Figure 2.

[0073] Each of the chamber assemblies *(10010)* and *(10020)* includes a shared input conduit *(10040)* that delivers input gases to a top input plenum *(10050)* and a

sensor or the like for determining the effectiveness of the trap so that gas flow can be redirected to the other parallel path to take advantage of a more effective trap set. Accordingly, the trapping configuration of Figure 15 may be used to considerably extend the number of coating cycles that a gas deposition coating system can complete before the traps need to be replaced.

[0085] Referring now to Figures 16A and 16B another embodiment of a reaction chamber assembly *(8100)* according to the present invention includes an outer wall assembly *(8110)* enclosing a hollow rectangular chamber *(8120)* sized to support six substrate support shelves *(8130)* disposed horizontally therein. As shown in Figure 16A a left support area *(8140)* include three horizontally supported substrate shelves stacked one above another and a right support area *(8150)* that includes an additional three horizontally supported substrate shelves stacked one above another. The reaction chamber assembly *(8100)* further includes an input plenum *(8160)*, an output plenum *(8170)* and an exit port module *(8180)* all similar in design and function to above described modules of the same name. A front face, not shown, of the reaction chamber assembly *(8100)* includes a front rectangular aperture and associated movable access door, similar in design and function to above described modules of the same name, to provide access to the hollow rectangular chamber *(8120)* to load and unload one or more substrates onto each of the six substrate support shelves *(8130)*.

[0086] Preferably, each of the six substrate support shelves *(8130)* is rectangular, is substantially identical, and is sized to receive a single rectangular substrate thereon ranging in size from GEN 1.0 (300 x 400 mm) to GEN 7 (2160 x 2460 mm) with the shelves configured to support the substrate short dimension or transverse width along the x-axis with the substrate long dimension or longitudinal length supported along the y-axis.

[0087] As with the reaction chamber assemblies described above, a right rectangular aperture *(8190)* extends along the entire longitudinal length or y-axis dimension of each substrate support shelf *(8130)* and receives input gas or vapor from the input

1. A reaction chamber assembly *(3000, 8100)* for depositing thin film layers onto one or more substrates comprising:
   - an outer wall assembly for enclosing a hollow chamber comprising substantially opposing top and bottom outer walls *(3010, 3020)* attached to substantially opposing left and right outer side walls *(3030, 3040)* and substantially opposing front and back outer walls *(3042, 3044)*;
   - a gas supply module for delivering one or more gas and vapor phase materials into the hollow chamber;
   - a vacuum pump for removing gas and vapor phase materials from the hollow chamber;
   - characterized in that the reaction chamber assembly further comprises:
   - an input rectangular aperture *(3140)* extending through one of the left and right outer side walls *(3030), (3040)*;
   - an output rectangular aperture *(3130)* extending through the other of the left and right outer side walls *(3040)* wherein the input rectangular aperture and the output rectangular aperture are opposing with substantially identical aperture dimensions;
   - an input plenum *(3150)* disposed external to the outer wall assembly and in fluid communication with the gas supply module for delivering the one or more gas and vapor phase materials into the hollow chamber through the input rectangular aperture; and,
   - an output plenum *(3250)* disposed external to the outer wall assembly and in fluid communication with the vacuum pump for removing gas and vapor phase materials from the hollow chamber through the output rectangular aperture.

2. ~~The reaction chamber assembly of claim 1 further comprising one or more substrate~~ support surfaces *(3350, 8130)* substantially horizontally disposed inside the hollow chamber and between the input and output rectangular apertures.

3. The reaction chamber assembly of claim 2 further comprising:

- a front aperture *(3035)* passing through the front outer wall *(3042)* for providing access to the hollow chamber *(3070)* for loading and unloading the one or more substrates; and,
- an access door *(3080)* movable with respect to the front aperture for gas sealing the front aperture during deposition coating cycles when the access door is closed and for providing access to the hollow volume through the front aperture when the access door is opened.

4. The reaction chamber of claim 2 wherein the input plenum forms an input plenum chamber *(3210)* having an input end that receives the one or more gas and vapor phase materials from the gas supply module through an input port *(3220)* disposed proximate to the input end and an output end that delivers the one or more gas and vapor phase materials into the hollow chamber through the rectangular input aperture *(3130)* and wherein the input plenum chamber is shaped to substantially continuously expand in volume from the input end to the output end.

5. The reaction chamber assembly of claim 4 wherein the input plenum chamber *(3210)* has a first triangular cross-section in a substantially horizontal plane with the input end forming an apex of the first triangular cross-section and the output end forming a base of the first triangular cross-section and further wherein the output end is in fluid communication with the hollow chamber through the rectangular input aperture *(3130)*.

6. The reaction chamber assembly of claim 5 wherein the input plenum chamber has a second trapezoidal cross-section in a substantially vertical plane with the input end

forming an apex of the second trapezoidal cross-section and the output end forming a base of the second trapezoidal cross-section.

7. The reaction chamber of claim 6 wherein the output plenum *(3250)* forms an output plenum chamber *(3300)* having an output end for removing the gas and vapor phase materials from the output plenum chamber through an exit port module *(3220)* disposed proximate to the output end and an input end for withdrawing the one or more gas and vapor phase materials out of the hollow chamber through the corresponding one of the left and right rectangular apertures and wherein the output plenum chamber is shaped to substantially continuously decrease in volume from the input end to the output end.

8. The reaction chamber assembly of either on of claims 2 and 7 wherein the output plenum chamber *(3300)* has a first triangular cross-section substantially in a horizontal plane with the output end forming an apex of the first triangular cross-section and the input end forming a base of the first triangular cross-section and further wherein the input end is in fluid communication with the hollow chamber through the rectangular output aperture *(3140)*.

9. The reaction chamber assembly of claim 8 wherein the output plenum chamber has a second trapezoidal cross-section substantially in a vertical plane with the output end forming an apex of the second trapezoidal cross-section and the input end forming a base of the second trapezoidal cross-section.

10. The reaction chamber assembly of claim 9 wherein the exit port module comprises:

- a circular exit port *(3310)* passing through one of a top and a bottom output plenum wall;
- a pressure gage for sensing gas pressure inside the exit port module; and,
- a stop valve for isolating the exit port module from the vacuum pump when the stop valve is in a closed position.

11. The reaction chamber of claim 2 wherein the hollow volume has a first rectangular cross-section in a substantially horizontal plane with a hollow volume longitudinal length and a hollow volume transverse width wherein each of the one or more substrate support surfaces *(3350, 8130)* has rectangular dimensions with a support surface longitudinal length and a support surface transverse width each sized to fit inside the hollow volume first rectangular cross-section and to support a rectangular substrate having rectangular dimensions defined any one of the substrate size standards GEN 1 (300x400 mm) through GEN 7 (2160 x 2460 mm).

12. The reaction chamber of claim 2 further comprising a liner assembly *(6000)* disposed inside the hollow chamber and configured to prevent the one or more gas and vapor phase materials from contaminating inside surfaces of the outer wall assembly.

13. The reaction chamber assembly of claim 12 wherein the liner assembly includes a substantially horizontally disposed liner base wall *(6010)* positioned between the left and right apertures *(3030, 3040)* and wherein the liner base wall comprises the one or more substrate support surfaces.

14. The reaction chamber assembly of claim 13 wherein the liner assembly *(6000)* is configured for installation into and removal from the hollow chamber through the front aperture *(3035)*.

15. The reaction chamber of claim 13 further comprising a back aperture *(3045)* passing through a back outer wall *(3044)* of the outer wall assembly wherein the liner assembly is configured for installation into and removal from the hollow chamber through the back aperture *(3045)*.

16. The reaction chamber of either one of claims 14 and 15 further comprising an input plenum liner *(7015)* comprising a rectangular tube shaped element installed through the rectangular input aperture associated to prevent the gas and vapor phase materials

flowing through the rectangular input aperture from contaminating inside surfaces of the outer walls.

17. The reaction chamber of claim 16 further comprising an output plenum liner *(7080)* comprising a rectangular tube shaped element installed through the rectangular output aperture to prevent the gas and vapor phase materials flowing through the rectangular output aperture from contaminating inside surfaces of the outer walls.

18. The reaction chamber assembly of claim 1 wherein the reaction chamber *(3000)* comprises an upper reaction chamber *(1120)* further comprising:

- a frame *(1140)* for supporting the upper reaction chamber *(1120)* in an upper position on the frame;
- a second substantially identical bottom reaction chamber *(1150)* supported in a bottom position on the frame *(1140)*.

19. The reaction chamber of claim 18 further comprising:

- a plurality of first subsystems associated with the upper reaction chamber supported on the frame
- a plurality of second subsystems associated with the bottom reaction chamber supported on the frame; and,
- wherein the upper reaction chamber and first subsystems operate independently of and may operate simultaneously with the bottom reaction chamber and second subsystems.

20. The reaction chamber of claim 19 further comprising a single gas supply module *(10030)* delivering gas or vapor phase materials into each of an upper input plenum *(10050)* associated with the upper reaction chamber *(1120)* and a bottom input plenum *(10060)* associated with the bottom reaction chamber *(1150)*.

21. The reaction chamber of claim 20 further comprising a single exit port module in fluid communication with a vacuum pump for removing gas and vapor materials from each of an upper output plenum *(10090)* associated with upper reaction chamber and a bottom output plenum *(10100)* associated with the bottom reaction chamber.

22. The reaction chamber of claim 1 further comprising a trap disposed between the exit plenum and the vacuum pump wherein the trap includes a catalytically active hydrocarbon (HC) oxidation matrix suitable for reacting with undesirable hydrocarbon gases being withdrawn from the exit plenum.

23. A method for depositing thin film layers onto rectangular substrates that have a substrate longitudinal length and a substrate transverse width wherein at least one substrate is supported in a hollow rectangular chamber enclosed by an outer wall assembly comprising the steps of:
- delivering one or more gas and vapor phase materials into an input plenum disposed external to the outer wall assembly between the hollow rectangular chamber and a gas supply module;
- expanding the volume of the one or more gas and vapor phase materials inside the input plenum; and,
- delivering the one or more gas and vapor phase materials into the hollow rectangular chamber through a rectangular input aperture passing through a first side wall of the outside wall assembly, wherein the rectangular input aperture has a longitudinal aperture dimension that is centered with respect to and equal to or greater than one of the substrate longitudinal length and the substrate transverse width.

24. The method of claim 23 further comprising the step of drawing the gas or vapor phase material out of the hollow rectangular chamber through an rectangular output aperture passing through a second side wall of the outside wall assembly opposed to the rectangular input aperture wherein the input and output apertures have

substantially identical rectangular dimensions and further drawing the gas and vapor phase material into an output plenum disposed externally to the outer wall assembly between the hollow rectangular chamber and a vacuum pump.

25. The method of claim 24 further comprising the step of compressing the volume of the one or more gas and vapor phase materials in the output plenum.

26. The method of claim 25 further wherein the one or more gas and vapor phase materials being drawn out of the hollow rectangular chamber comprises undesirable hydrocarbon materials further comprising the step of reacting the undesirable hydrocarbon materials with a catalytically active hydrocarbon (HC) oxidation matrix disposed in a trap positioned between the output plenum and the vacuum pump.

ALD SYSTEMS AND METHODS

1.1 Cross Reference to Related U.S. Patent Applications

[0001] The present application claims priority to U.S. Provisional Patent Application Serial No. 61/208875 filed 02/27/2009, which is incorporated herein by reference in its entirety and for all purposes.

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1.3 Background

1.4 Field

[0003] The exemplary, illustrative, technology herein relates to atomic layer deposition (ALD) systems and operating methods thereof and to gas deposition chamber and subsystem configurations that are compatible with robotic large substrate loading and unloading, with autonomous ALD coating operations, and with generating desired gas flow patterns over large rectangular substrates as well as extending the operating time between maintenance procedures so as to enhance production rates.

[0004] The technology herein has applications in the areas of producing single or multiple material monolayer coatings such as those useful for constructing Liquid Crystal Display (LCD) devices.

1.5 The Related Art

[0005] Gas, or vapor, deposition is a method for creating thin material layers (coating) on surfaces that involves exposing a solid substrate surface to a gas or vapor,

walls. Such a liner can be removed from the chamber, cleaned by an acid etch or the like, and then reinstalled into the chamber. One such removable liner is disclosed in co-pending and commonly assigned U.S. Provisional Patent Application No. 61/197,948 filed on November 1, 2008 entitled GAS DEPOSITION CHAMBER WITH REMOVABLE LINER which is incorporated herein by reference in its entirety and for all purposes.

[0012] A further problem with advancing ALD coating systems to commercially viable operation is the need to reduce coating cycle time and this includes the time required to load and unload a substrate, to heat the chamber and substrate to the deposition temperature, to pump the chamber to deep vacuum, to purge contaminants from the chamber, to expose the substrate to precursor gases and to flush the precursor gases out of the chamber. Applicants have found that cycle time can be reduced when the substrate is exposed to a laminar gas flow substantially over its entire coating surface and that this can be accomplished by controlling the velocity and path of input gasses by careful design of an input plenum that distributes the gas over the width of a substrate and reduces the gas velocity.

[0013] A further problem with advancing ALD coating systems to commercially viable operation is the need to fit ALD coating systems into existing production facilities where floor space is at premium. Accordingly, there is a need in the art for an ALD production coating device that provides high coating throughput in a small floor space footprint.

1.6 Summary

[0013a] The invention is defined in the independent claims. Some optional features are defined in the dependent claims.

[0014] These and other problems are addressed by the present disclosure, which provides a gas deposition system (1000) configured as a dual-chamber "tower", including a frame (1140) for supporting two reaction chamber assemblies (3000), one vertically above the other. The present disclosure further provides a gas deposition chamber (3000) and associated gas control systems configured to deposit thin film

plate is lowered to a down position the pin tops are lowered below the substrate support surface (3350) and the substrate is lowered into contact with the substrate support surface (3350).

[0021] In some embodiments the two chamber assemblies may be driven by one gas supply module and evacuated by one vacuum pump and the system controller includes program steps suitable for performing substantially simultaneous coating cycles in both chambers.

[0022] In some embodiments a precursor trap (10140) may be disposed in the exit port module (3320). In further embodiments one or more additional trap elements may be disposed between the exit port and the vacuum pump.

[0023] These and other aspects and advantages will become apparent when the Description below is read in conjunction with the accompanying Drawings.

1.7 Brief Description of the several views of the Drawings

[0024] Figure 1 depicts an isometric view showing a dual chamber gas deposition system without external skins.

[0025] Figure 2 depicts a plan view of an automated production facility that includes one or more dual chamber gas deposition systems.

[0026] Figure 3 depicts a front isometric front view of a gas deposition chamber assembly:

[0027] Figure 4 depicts a back isometric back view of a gas deposition chamber assembly:

[0028] Figure 5 depicts an isometric view of showing section A-A taken through a gas deposition chamber assembly.

[0029] Figure 6 depicts an isometric view of a welded chamber liner assembly.

[0030] Figure 7 depicts schematic representation of an exploded section view showing a substrate supported on the chamber liner assembly and a pair of plenum liners.

[0031] Figure 8 depicts a side view of the top of a lift pin.

[0032] Figure 9 depicts a top schematic view of a double wide gas deposition chamber.

[0033] Figure 10 depicts a front schematic view of dual chamber system having a gas supply module connected to both chambers and a vacuum pump connected to both chambers.

[0034] Figure 11 depicts a front schematic view of a dual chamber system with an input plenum associated with one chamber an output plenum associated with the outer chamber and a rectangular conduit connecting the two chambers together in series.

[0035] Figure 12 depicts an isometric view of a rectangular fluid conduit.

[0036] Figure 13 depicts first and second traps disposed in series between an output plenum and a vacuum pump wherein a stop valve is positioned between the second trap and the vacuum pump.

[0037] Figure 14 depicts first and second traps disposed in series between an output plenum and a vacuum pump wherein a stop valve is positioned between the first and the second trap

[0038] Figure 15 depicts first second trap disposed in parallel fluid conduits extending from an output plenum and a vacuum pump wherein each parallel fluid conduit includes a stop valve and one or more additional traps.

3440 Guide rods	12020 Lower flange/port
3450 Stiffening Fins	12030 Rectangular fluid conduit

13010 Output plenum	
13020 Exit plenum	
13030 1st Precursor trap	
13040 Auxiliary precursor trap	
13050 Stop valve	
13060 Second Trap	
13070 T-fitting	
13080 Stop valve	
13090 Stop valve	
13120 Left conduit	
13130 Right conduit	
13140 Auxiliary precursor trap	
13150 Auxiliary precursor trap	
13160 Second Trap	

1.8 Detailed description

Frame control system gas supply system and Figure 1

[0041] Referring to Figure 1, a preferred exemplary implementation of a dual chamber gas deposition system (1000) is shown in isometric view with the external skins removed. The system (1000) includes a front face (1180) which is used for loading substrates into each of two gas deposition chambers (1120) and (1150). A right side face (1130) includes a single user interface device (1200) which can be used to enter commands for operating both of the gas deposition chambers (1120) and (1150). In alternate embodiments, each gas deposition chamber may include a separate user interface device (1200). In

further alternate embodiments, the control systems of both gas deposition chambers can be networked to a remote device that includes a remote user interface, not shown. The system (1000) comprises a frame (1140) constructed to support an upper ALD reaction chamber (1120) supported by an upper cross frame platform (1145) and a lower ALD reaction chamber (1150) supported by a lower cross frame platform (1155). Each of the chambers (1120) and (1150) is constructed to receive a single large area rectangular substrate therein and to support the substrate in a substantially horizontal plane. In particular, the preferred substrate size is a GEN 4.5 glass substrate which has rectangular dimensions of 920 mm wide by 730 mm deep and the chambers (1120) and (1150) are configured with a front opening or load port having a width dimension along an x-axis that is larger than 730 mm for receiving the substrate width dimension through the front port. Accordingly, the longitudinal length of the chamber along a Y-axis, defined in Figure 3, is greater than 920 mm to receive the GEN 4.5 substrate therein. Alternately, the chamber assembly can be configured to receive substrates in another orientation. Each substrate comprises a top face, to be coated, and an opposing bottom face that is not coated. The substrates have an approximate thickness of 0.5 mm, and are therefore fragile and difficult to handle. The glass substrates are used to manufacture rectangular LCD screens and the like. The chamber includes a horizontal substrate support surface for receiving a bottom face of a substrate thereon with an opposing top face of the substrate top face facing upward. Generally one GEN 4.5 substrate is loaded into a chamber at a time for coating; however, a plurality of smaller glass substrates can be loaded into a chamber (1120) or (1150) and coated simultaneously. In other embodiments, chamber assemblies for supporting larger or smaller rectangular substrates can be configured. A small chamber assembly may be configured to support a single GEN 1.0 (300 x 400 mm) substrate and a large chamber assembly may be configured to support a single GEN 7.0 (2160x2460 mm) substrate.

[0048] The robotic substrate handler (2010) moves the robotic base (2030) and the manipulator arm (2040) to guide the lifting elements (2050) through various wall ports (2080) to either pick up or drop off a substrate in a desired area. For example, to pick up an uncoated substrate from a storage rack (2020) the lifting elements (2050) are extended into the storage rack just below a horizontally supported substrate and then raised to lift and support the substrate on the lifting elements (2050). The robotic substrate handler (2010) then withdraws the substrate from the storage rack (2020) and transports the substrate to a selected chamber of one of the dual chamber gas deposition systems (1000) for insertion into the selected chamber through one of the top or bottom load ports (1190) or (1170). The selected chamber may comprise whichever chamber is ready to receive a new substrate for coating, because each chamber of the dual chamber systems (1000) communicates with the robotic substrate handler (2010) to request loading or unloading of a substrate or to open or close the load lock as required for loading and unloading. Accordingly, in the preferred embodiment, the dual chamber tower (1000) is configured for autonomous loading and unloading by a robotic substrate handler like the handler (2010) shown in Figure 2.

Chamber outer walls, eye hooks, heating elements and insulation Figures 3

[0049] Referring now to Figures 3-8 and 16, a gas deposition chamber assembly (3000) is shown in various views with like elements having the same reference number. The chamber (3000) is shown in front isometric view in Figure 3, in rear isometric view in Figure 4 and in section view with the section A-A being shown in Figure 5. As best viewed in the schematic view of Figures 5 and 5A, the chamber assembly (3000) comprises a plurality of outer walls formed by opposing top and bottom rectangular outer walls (3010) and (3020) attached to opposing left and right rectangular outer walls (3030) and (3040) and attached to opposing front and back outer walls (3042) and (3044) In one embodiment, each of the front and back outer walls (3042) and (3044) comprise a perimeter flange surrounding a rectangular aperture. A front rectangular aperture (3035) passes through the front outer wall (3010) and serves as a load port. A back rectangular aperture (3045), which is

external surfaces thereof or disposed as internal layers thereof for preventing thermal heat loss from the chamber assembly. The top outer wall (3010) includes a plurality of eye bolts (3125) suitable for lifting the chamber assembly (3000) into and out of the frame (1140) with an overhead hoist or the like.

[0051] Referring to Figures 3, 4 and 5A the reaction chamber assembly (3000) has rectangular cross-section in a substantially horizontal X-Y plane with a longitudinal length extending along the y-axis and a transverse width extending along the x-axis with a triangular input plenum (3150) attached to the right outer wall (3040), a triangular output plenum attached to the left outer wall (3030) and an load port and associated access door disposed at a front wall of the reaction chamber assembly. In other embodiments, the longitudinal length may extend along the x-axis with the transverse width extending along the y-axis . Additionally, the reaction chamber assembly has a height along a z-axis. Similarly, as shown in outer wall assembly of Figure 5A the hollow volume has a rectangular cross-section in an X-Y plane with a longitudinal length extending along the y-axis and a transverse width extending along the x-axis and a height along the z-axis. In the present example, rectangular substrates are loaded into the hollow volume and supported therein on one or more horizontally disposed substrate support surfaces with a longitudinal length of the substrate extending along the y-axis and a transverse width of the substrate extending along the x-axis.

Input and output plenums Figures 3-5

[0052] Referring now to Figures 3 and 5, the right outer wall (3040) extends along the Y-axis and is formed with a right rectangular through aperture (3130) open to the hollow rectangular chamber (3070). The right rectangular through aperture is substantially centered in the right side wall its position and Y-axis dimension substantially corresponds with the Y-axis position and dimension of a substrate positioned inside the hollow rectangular chamber (3070) for coating. An input plenum (3150) is attached to the right outer wall (3040) by an input plenum flange

substrate support surface (7010) such that a substrate supported on the pin tops is placed in contact with the substrate support surface (7010). Preferably the lift pins (7120) remain engaged with the through holes (7110) when the pins are lower to limit the flow of purge gas through the holes (7110) however the pins can be lowered to a position below the bottom liner wall (6010) as shown in Figure 7.

[0068] Referring now to Figure 8, an exemplary embodiment of a lift pin (8000) is shown in cutaway side view. The exemplary lift pin (8000) comprises a cylindrical metal shaft (8010) and a tip attachment (8020). The tip attachment comprises VESPEL®, a polymer made by DuPont, or another suitable polymer, and is attached to the metal shaft (8010) by bonding or other suitable fastening means. Ideally the tip attachment (8020) material is can withstand the temperature range and harsh chemical environment of the gas deposition chamber without damage while also providing low out gassing and high thermal and electrical insulation. The top end of the tip attachment (8020) is formed with a spherical end (8030).

[0069] Referring now to Figure 5, a pin actuator assembly (3390) is disposed outside the chamber assembly attached to an external surface of the bottom outer wall (3020). A lift post (3400) extends between a pneumatic cylinder and piston assembly (3410) and the movable pin plate (7130) by passing through a circular hole (3430) through the chamber bottom outer wall (3020) a vacuum bellows (3420). The vacuum bellows (3420) extends from the pneumatic cylinder and piston assembly (3410) to the chamber bottom outer wall and vacuum seals the circular through hole (3430). The pin actuator assembly (3390) further includes a pair of guide rods (3440) for guiding movement of the pneumatic cylinder and piston assembly (3410) and the lift post (3400). The system controller coordinates actuation of the pin actuator assembly to raise and lower the movable pin plate when the access door is open for the loading and unloading of substrates.

[0070] Referring to Figures 5 and 7, a substrate to be coated is installed into the hollow rectangular chamber (3070) by lowering the movable access door (3080) and raising the movable pin plate (7130). A substrate

(7000) is then inserted into the chamber by the robotic substrate handler (2010) or another insertion device and set down resting on the tops of the plurality of lift pins (7120). One dimension of the substrate (7000) is substantially centered between the input and output plenums (3150) and (3250) and the other dimension of the substrate is centered with respect to the left and right rectangular apertures (3130) and (3140). The movable pin plate (7130) is then lowered to set the substrate (7000) onto the substrate support surface (7110) and the access door (3080) is closed and vacuum sealed. The chamber is then heated to raise the substrate to the gas deposition temperature and the vacuum pump is started to pump the chamber down to a vacuum pressure. The chamber may also be purged with an inert gas during the initial pump down to remove contaminants such as water vapor. When the chamber is at the desired vacuum pressure and the substrate at the desired temperature, a gas deposition recipe can begin. Generally, the recipe begins by closing the stop valve (3330) and introducing a precursor gas into the chamber through the input port (3230). Alternately, the precursor can be introduced with the stop valve (3330) open and the vacuum pump operating. After the first precursor cycle, the chamber is purged by running the vacuum pump and flushing the chamber with a purge gas. The cycle is then repeated for a second precursor gas and the two precursor gas cycle may be repeated many thousands of times. When substrate coating is complete, the stop valve (3330) is closed and the chamber is purged to atmosphere through the input port or another port. The movable access door (3080) is opened and the movable pin plate (7130) is raised to lift the coated substrate from the substrate support surface. The robotic substrate handler (2010) then removes the coated substrate form the chamber and installs an uncoated substrate into the chamber for the next coating cycle.

[0071] Referring now to Figures 9 -11 additional embodiments relate to systems and methods for coating two or more substrates in a single chamber assembly, as is shown in Figure 9, or for driving two or more coating chamber assemblies with a single gas supply module and vacuum pump. In particular, Figure 9 depicts a top schematic view of double wide chamber assembly

(9000) configured to receive two rectangular glass substrates (9010) and (9020) disposed side by side on a horizontal support surface and with a double wide movable door (9030) supported for vertical movement to provide access through a front face of the chamber assembly to insert the two rectangular glass substrates (9010) and (9020). Otherwise the chamber assembly (9000) is substantially identical with the chamber assembly (3000) described above. In particular the chamber assembly (9000) utilizes the same input plenum (3150) disposed between one of the left and right plenum apertures and a gas supply module (3240) for delivering gas and vapor phase materials into the outer volume through the corresponding left or right plenum aperture supply module (3240) and the same output plenum (3250) and exit port module (3220) described above. Accordingly, the input plenum delivers a substantially laminar gas flow across the horizontal top surfaces of both of the rectangular glass substrates (9010) and (9020) before gas is removed from the double wide chamber through the exit port module (3220). In addition, a system controller used to control coating sequences in the chamber assembly (9000) may include coating recipes that are adjusted to deliver additional precursor gas volume into the double wide chamber as may be required to ensure that both substrates are uniformly coated.

[0072] Referring now to Figures 10 and 11, two additional embodiments are shown schematically. In Figure 10 a dual chamber system (10000) includes two chamber assemblies (10010) and (10020) that are each substantially identical to the chamber assembly (3000) described above except that the two chamber assemblies (10010) and (10020) share a common gas supply module (10030) and a common vacuum pump, not shown. Moreover, the two chamber assemblies (10010) and (10020) may be mounted in the frame (1140), described above and shown in Figure 1, such that the system (10000) can replace a dual tower system (1000) in the automated production facility (2000) described above and shown in Figure 2.

[0073] Each of the chamber assemblies (10010) and (10020) includes a shared input conduit (10040) that delivers input gases to a top input plenum (10050) and a

sensor or the like for determining the effectiveness of the trap so that gas flow can be redirected to the other parallel path to take advantage of a more effective trap set. Accordingly, the trapping configuration of Figure 15 may be used to considerably extend the number of coating cycles that a gas deposition coating system can complete before the traps need to be replaced.

[0085] Referring now to Figures 16A and 16B another embodiment of a reaction chamber assembly (8100) includes an outer wall assembly (8110) enclosing a hollow rectangular chamber (8120) sized to support six substrate support shelves (8130) disposed horizontally therein. As shown in Figure 16A a left support area (8140) include three horizontally supported substrate shelves stacked one above another and a right support area (8150) that includes an additional three horizontally supported substrate shelves stacked one above another. The reaction chamber assembly (8100) further includes an input plenum (8160), an output plenum (8170) and an exit port module (8180) all similar in design and function to above described modules of the same name. A front face, not shown, of the reaction chamber assembly (8100) includes a front rectangular aperture and associated movable access door, similar in design and function to above described modules of the same name, to provide access to the hollow rectangular chamber (8120) to load and unload one or more substrates onto each of the six substrate support shelves (8130).

[0086] Preferably, each of the six substrate support shelves (8130) is rectangular, is substantially identical, and is sized to receive a single rectangular substrate thereon ranging in size from GEN 1.0 (300 x 400 mm) to GEN 7 (2160 x 2460 mm) with the shelves configured to support the substrate short dimension or transverse width along the x-axis with the substrate long dimension or longitudinal length supported along the y-axis.

[0087] As with the reaction chamber assemblies described above, a right rectangular aperture (8190) extends along the entire longitudinal length or y-axis dimension of each substrate support shelf (8130) and receives input gas or vapor from the input

CLAIMS

1. A reaction chamber assembly *(3000, 8100)* for depositing thin film layers onto one or more substrates comprising:

- an outer wall assembly for enclosing a hollow chamber comprising opposing top and bottom outer walls *(3010, 3020)* attached to opposing left and right outer side walls *(3030, 3040)* and opposing front and back outer walls *(3042, 3044)*;

- a gas supply module for delivering one or more gas and vapor phase materials into the hollow chamber;

- a vacuum pump for removing gas and vapor phase materials from the hollow chamber;

characterized in that the reaction chamber assembly further comprises:

- an input rectangular aperture *(3130)* extending through one of the left and right outer side walls *(3030), (3040)*;

- an output rectangular aperture *(3140)* extending through the other of the left and right outer side walls *(3040)* wherein the input rectangular aperture and the output rectangular aperture are opposing with identical aperture dimensions;

- an input plenum *(3150)* disposed external to the outer wall assembly and in fluid communication with the gas supply module for delivering the one or more gas and vapor phase materials into the hollow chamber through the input rectangular aperture;

- an output plenum *(3250)* disposed external to the outer wall assembly and in fluid communication with the vacuum pump for removing gas and vapor phase materials from the hollow chamber through the output rectangular aperture; and,

- one or more substrate support surfaces *(3350, 8130*) horizontally disposed inside the hollow chamber and between the input and output rectangular apertures,

wherein the output plenum *(3250)* forms an output plenum chamber *(3300)* having an output end for removing the gas and vapor phase materials from the output plenum chamber through an exit port module *(3220)* disposed proximate to the output end and an input end for withdrawing the one or more gas and vapor phase materials out of the hollow chamber through the corresponding one of the left and right rectangular apertures and wherein the output plenum chamber is shaped to continuously decrease in volume from the input end to the output end,

wherein the output plenum chamber *(3300)* has a first triangular cross-section in a horizontal plane with the output end forming an apex of the first triangular cross-section and the input end forming a base of the first triangular cross-section and further wherein the input end is in fluid communication with the hollow chamber through the output rectangular aperture *(3140),*

wherein the output plenum chamber has a second trapezoidal cross-section in a vertical plane with the output end forming an apex of the second trapezoidal cross-section and the input end forming a base of the second trapezoidal cross-section,

wherein the exit port module comprises:

- a circular exit port *(3310)* passing through one of a top and a bottom output plenum wall;

- a pressure gauge for sensing gas pressure inside the exit port module; and,

- a stop valve for isolating the exit port module from the vacuum pump when the stop valve is in a closed position.

2. The reaction chamber assembly of claim 1 further comprising:

- a front aperture *(3035)* passing through the front outer wall *(3042)* for providing access to the hollow chamber *(3070)* for loading and unloading the one or more substrates; and,

- an access door *(3080)* movable with respect to the front aperture for gas sealing the front aperture during deposition coating cycles when the access door is closed and for providing access to the hollow volume through the front aperture when the access door is opened.

3. The reaction chamber of claim 1 wherein the input plenum forms an input plenum chamber *(3210)* having an input end for receiving the one or more gas and vapor phase materials from the gas supply module through an input port *(3220)* disposed proximate to the input end and an output end for delivering the one or more gas and vapor phase materials into the hollow chamber through the input rectangular aperture *(3130)* and wherein the input plenum chamber is shaped to continuously expand in volume from the input end to the output end.

4. The reaction chamber assembly of claim 3 wherein the input plenum chamber *(3210)* has a first triangular cross-section in a horizontal plane with the input end forming an apex of the first triangular cross-section and the output end forming a base of the first triangular cross-section and further wherein the output end is in fluid communication with the hollow chamber through the input rectangular aperture *(3130)*.

5. The reaction chamber assembly of claim 4 wherein the input plenum chamber has a second trapezoidal cross-section in a vertical plane with the input end forming an apex of the second trapezoidal cross-section and the output end forming a base of the second trapezoidal cross-section.

6. The reaction chamber of claim 1 wherein the hollow volume has a first rectangular cross-section in a horizontal plane with a hollow volume longitudinal length and a hollow volume transverse width wherein each of the one or more substrate support surfaces *(3350, 8130)* has rectangular dimensions with a support surface longitudinal length and a support surface transverse width each sized to fit inside the hollow volume first rectangular cross-section and to support a rectangular substrate having rectangular dimensions defined any one of the substrate size standards GEN 1 (300x400 mm) through GEN 7 (2160 x 2460 mm).

7. A reaction chamber assembly *(3000, 8100)* for depositing thin film layers onto one or more substrates comprising:

- an outer wall assembly for enclosing a hollow chamber comprising opposing top and bottom outer walls *(3010, 3020)* attached to opposing left and right outer side walls *(3030, 3040)* and opposing front and back outer walls *(3042, 3044)*;
- a gas supply module for delivering one or more gas and vapor phase materials into the hollow chamber;

- a vacuum pump for removing gas and vapor phase materials from the hollow chamber;

characterized in that the reaction chamber assembly further comprises:

- an input rectangular aperture *(3130)* extending through one of the left and right outer side walls *(3030), (3040)*;

- an output rectangular aperture *(3140)* extending through the other of the left and right outer side walls *(3040)* wherein the input rectangular aperture and the output rectangular aperture are opposing with identical aperture dimensions;

- an input plenum *(3150)* disposed external to the outer wall assembly and in fluid communication with the gas supply module for delivering the one or more gas and vapor phase materials into the hollow chamber through the input rectangular aperture;

- an output plenum *(3250)* disposed external to the outer wall assembly and in fluid communication with the vacuum pump for removing gas and vapor phase materials from the hollow chamber through the output rectangular aperture;

- one or more substrate support surfaces *(3350, 8130*) horizontally disposed inside the hollow chamber and between the input and output rectangular apertures; and

- a liner assembly *(6000)* disposed inside the hollow chamber and configured to prevent the one or more gas and vapor phase materials from contaminating inside surfaces of the outer wall assembly,

wherein the liner assembly includes a horizontally disposed liner base wall *(6010)* positioned between the left and right apertures *(3030, 3040)* and wherein the liner base wall comprises the one or more substrate support surfaces.

8. The reaction chamber assembly of claim 7 wherein the liner assembly *(6000)* is configured for installation into and removal from the hollow chamber through the front aperture *(3035)*.

9. The reaction chamber of claim 7 further comprising a back aperture *(3045)* passing through a back outer wall *(3044)* of the outer wall assembly wherein the liner assembly is configured for installation into and removal from the hollow chamber through the back aperture *(3045)*.

10. The reaction chamber of either one of claims 8 and 9 further comprising an input plenum liner *(7015)* comprising a rectangular tube shaped element installed through the input rectangular aperture associated to prevent the gas and vapor phase materials flowing through the input rectangular aperture from contaminating inside surfaces of the outer walls.

11. The reaction chamber of claim 10 further comprising an output plenum liner *(7080)* comprising a rectangular tube shaped element installed through the output rectangular aperture to prevent the gas and vapor phase materials flowing through the output rectangular aperture from contaminating inside surfaces of the outer walls.

12. The reaction chamber assembly of claim 1 wherein the reaction chamber *(3000*) comprises an upper reaction chamber *(1120)* further comprising:

- a frame *(1140)* for supporting the upper reaction chamber *(1120)* in an upper position on the frame;

- a bottom reaction chamber *(1150)* supported in a bottom position on the frame *(1140)*.

13. The reaction chamber of claim 12 further comprising:

- a plurality of first subsystems associated with the upper reaction chamber supported on the frame
- a plurality of second subsystems associated with the bottom reaction chamber supported on the frame; and,
- wherein the upper reaction chamber and first subsystems are operable independently of and may operate simultaneously with the bottom reaction chamber and second subsystems.

14. The reaction chamber of claim 13 further comprising a single gas supply module *(10030)* for delivering gas or vapor phase materials into each of an upper input plenum *(10050)* associated with the upper reaction chamber *(1120)* and a bottom input plenum *(10060)* associated with the bottom reaction chamber *(1150)*.

15. The reaction chamber of claim 14 further comprising a single exit port module in fluid communication with a vacuum pump for removing gas and vapor materials from each of an upper output plenum *(10090)* associated with upper reaction chamber and a bottom output plenum *(10100)* associated with the bottom reaction chamber.

16. The reaction chamber of claim 1 further comprising a trap disposed between the exit plenum and the vacuum pump wherein the trap includes a catalytically active hydrocarbon (HC) oxidation matrix for reacting with hydrocarbon gases being withdrawn from the exit plenum.