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Application Number: **Sheet No.: 1/6**

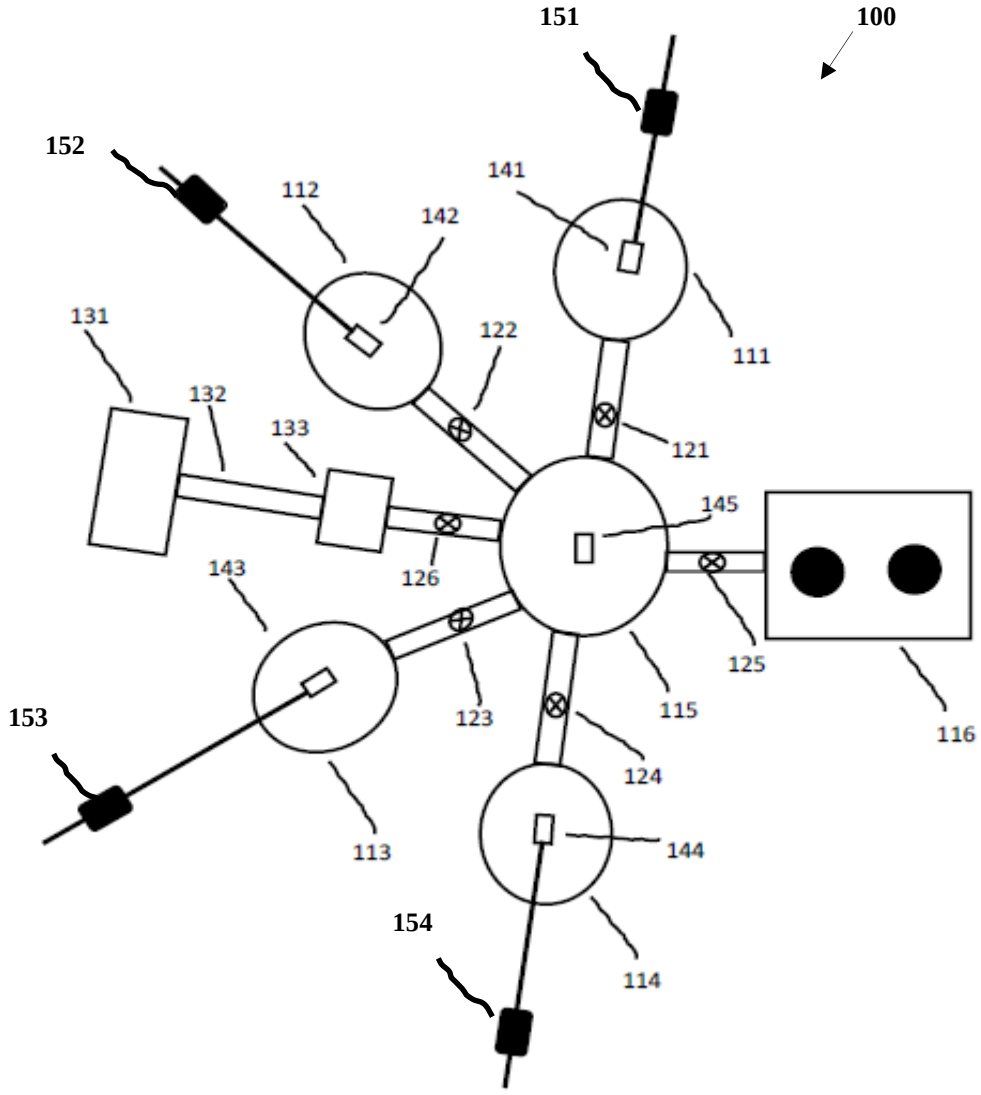


FIG. 1

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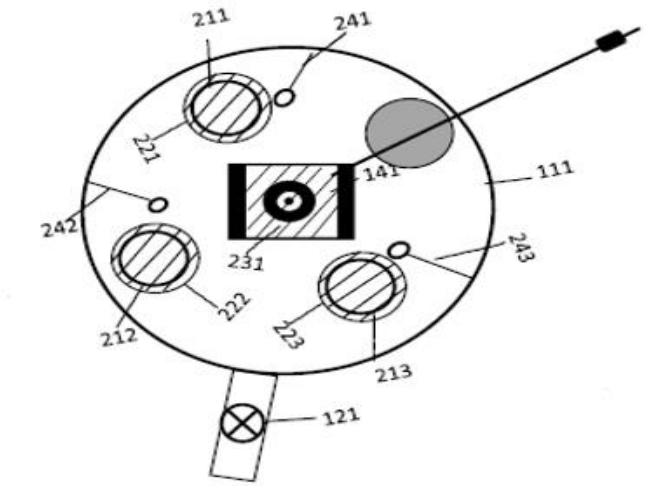


FIG. 2A

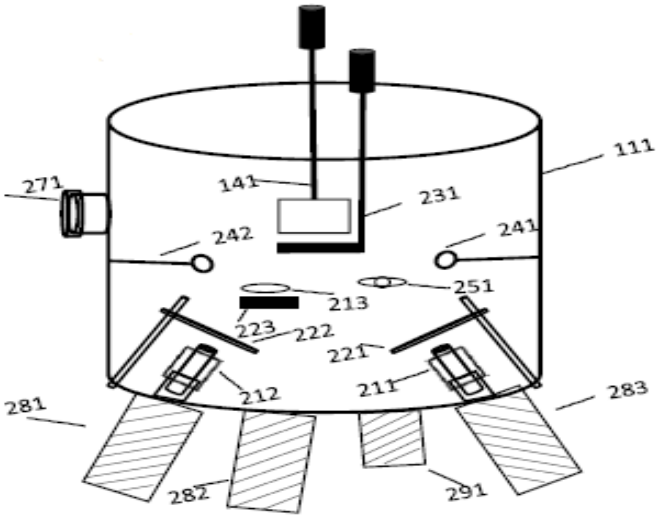


FIG. 2B

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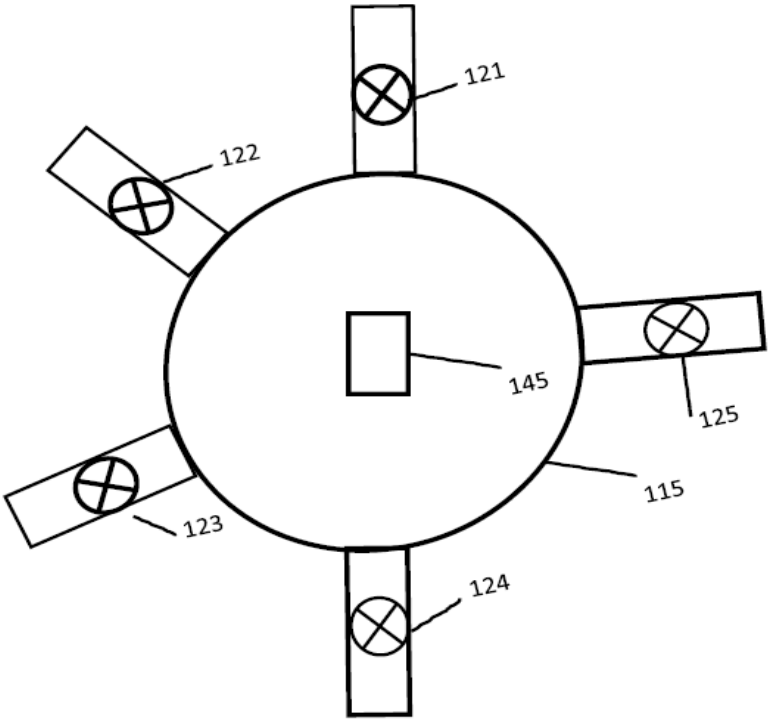


FIG. 3

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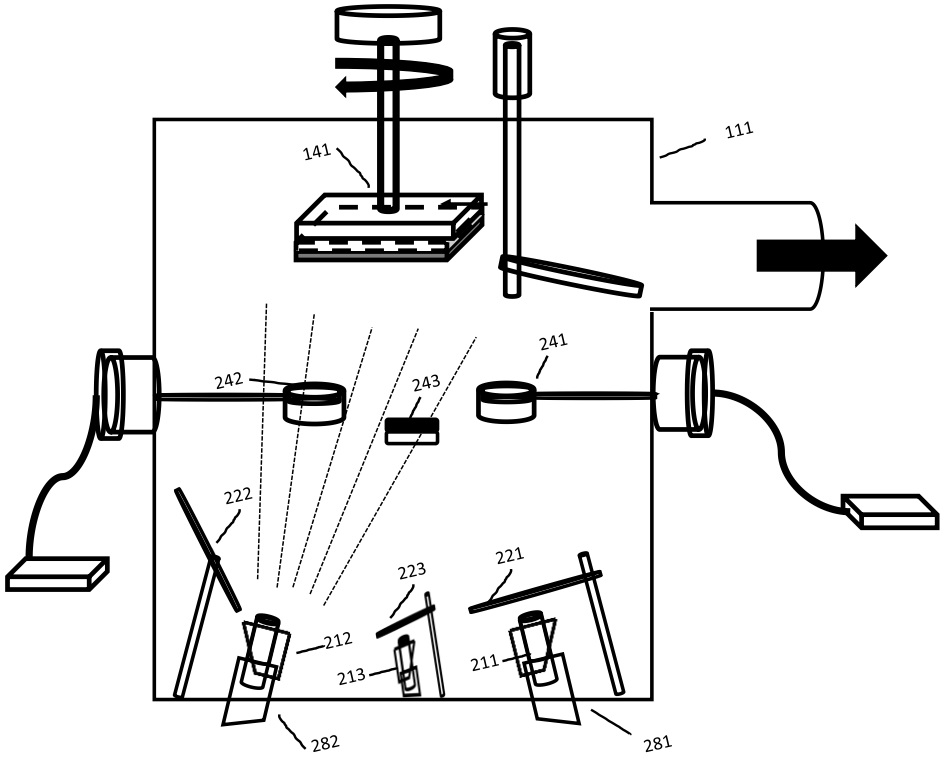


FIG. 4

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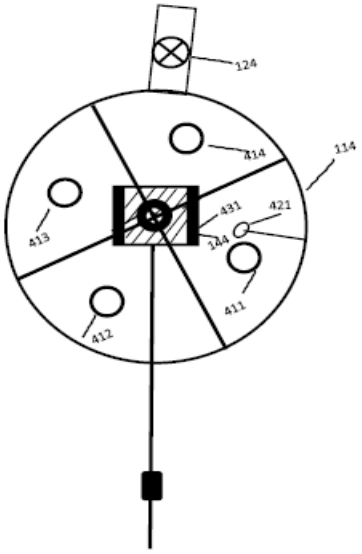


FIG. 5A

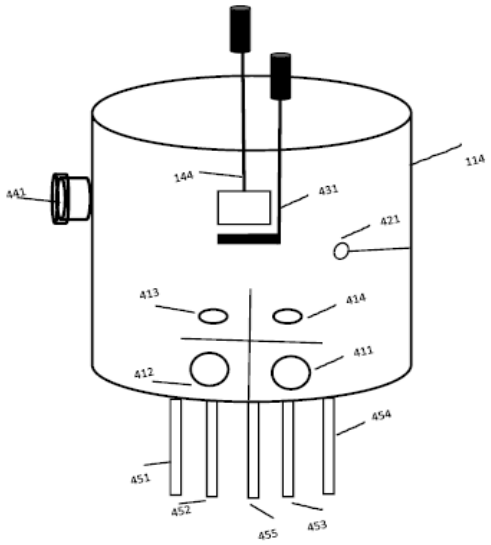


FIG. 5B

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Name of the Applicant:

Total No Of Sheets: 6
Application Number: **Sheet No.: 6/6**

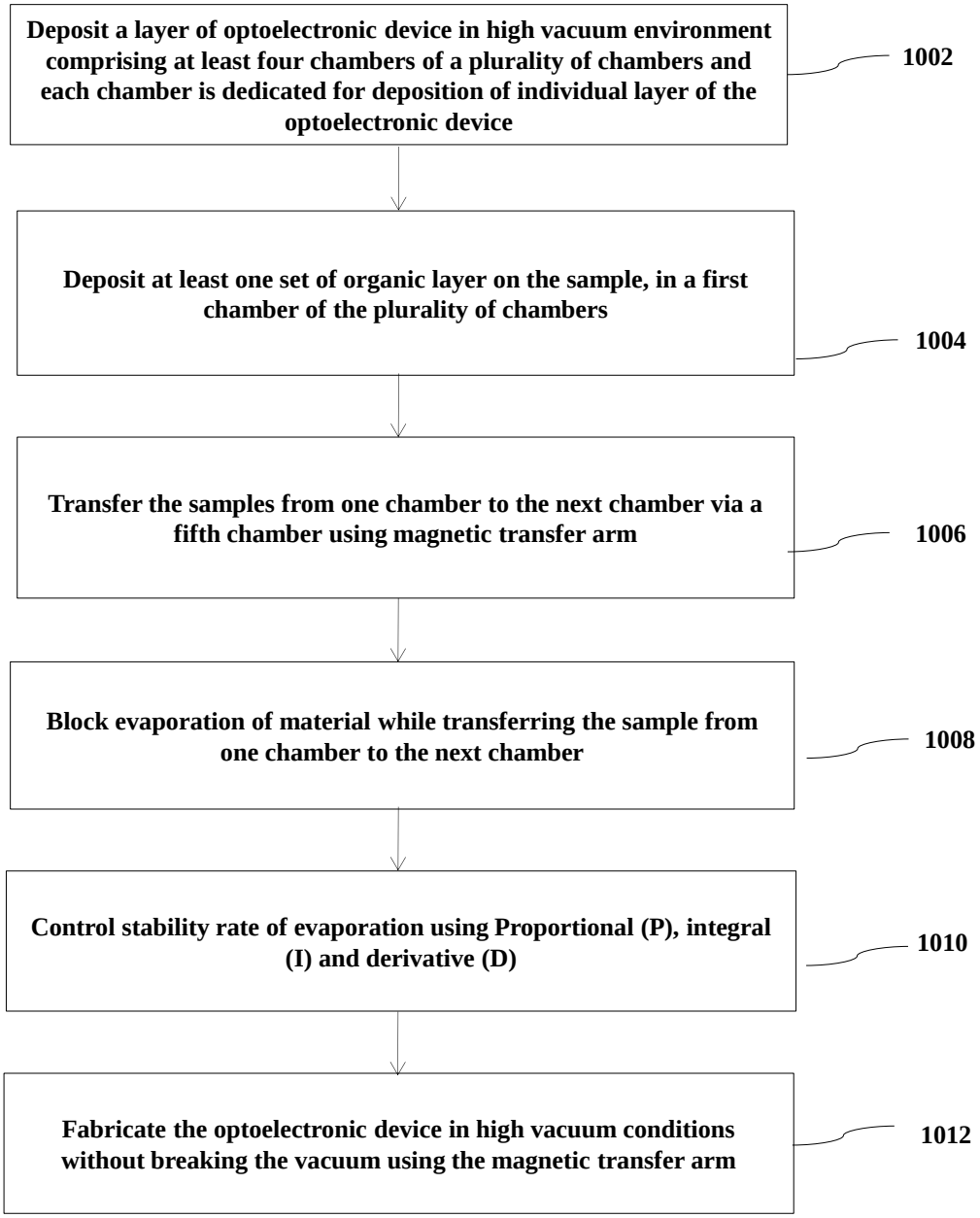


FIG. 6

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FORM 2

The Patent Act 1970

(39 of 1970)

&

The Patent Rules, 2005

COMPLETE SPECIFICATION

(SEE SECTION 10 AND RULE 13)

TITLE OF THE INVENTION

"System and Method for Fabrication of Multi-layer Thin Film Optoelectronic Devices"

APPLICANTS:

Name : **Indian Institute of Technology Bombay**

Nationality : **Indian.**

Address : **Powai Mumbai Maharashtra India- 400076.**

The following specification particularly describes and ascertains the nature of this invention and the manner in which it is to be performed:-

FIELD OF INVENTION

[0001] The embodiments disclosed herein generally relates to multi-purpose glove box, and more particularly, to a system for fabrication of vacuum based optoelectronic devices.

BACKGROUND OF THE INVENTION

[0002] In general, scientific experiments such as chemistry, biology, medicine and pharmacology, physics, electronics, need special operating environment. Such in electrochemical research field, during assembling devices such as lithium ion battery, lithium electrode is very active, oxidizable under the environment having oxygen, and the water molecule reaction also easily and in air goes bad. Therefore, chemical reaction also needs to carry out under inert gas shielding. Commercial glove box systems comes with a single chamber integrated inside an inert gas filled glove boxes for lab-scale research. The glove boxes contain a limitation of cross contamination and also the glove boxes consumes larger portion of space. Therefore, there is a need for a device to avoid the cross contamination inside the glove box and the glove box with wide application range.

[0003] Thus, it is desired to address the above mentioned disadvantages or other shortcomings or at least provide a useful alternative.

OBJECT OF INVENTION

[0004] A principal objective of the invention is to provide a system and method for fabricating a multi-layer thin-film optoelectronic device.

[0005] Another objective of the invention is to avoid cross contamination in multi-layer thin-film optoelectronic device by providing a special arrangement to ensure until device fabrication is completed, sample does not get exposed to ambient.

SUMMARY

[0006] Embodiments disclosed herein provide a system for fabricating a multi-layer thin film optoelectronic device comprising at least one chamber of a plurality of chambers for deposition of layers on a sample and a number of chambers and chamber size of the plurality of chambers are expanded as per requirement. Further, the system comprises at least one chamber of the plurality of chambers for deposition of top electrodes and a fifth chamber connected to the at least one chambers and the fourth chamber. Furthermore, the system comprises the glove box is connected to the fifth chamber to remove the samples out of the fifth chamber and a Quartz Crystal Monitor (QCM) of the chambers comprises an orifice for guided evaporation. Furthermore, the system comprises a plurality of pneumatic gate valves for transferring the samples from one chamber to the next chamber of the at least one chamber through the fifth chamber using magnetic transfer arms and a Turbo-molecular Pump is connected to the fifth chamber for evacuating the at least one chambers and the at least one fourth chamber. Finally, the optoelectronic device comprises a sample holder for each chamber.

[0007] In an embodiment, the deposition of layers comprises at least one of organic, inorganic, hybrid layers on the sample.

[0008] In an embodiment, the at least one chamber comprises plurality of compartments with multiple effusion cells for deposition of layers to make the system cost effective.

[0009] In an embodiment, the deposition of the top electrodes comprises deposition of one of: metal, metal oxide, metal halides, metal carbonates.

[0010] In an embodiment, the TMP (133) is connected to a rotary vane pump via bellow for backing evacuation of the chambers to high vacuum of approximately 1*10-6 mbar.

[0011] In an embodiment, the backing evacuation of the chambers is performed using a portable pump station for evacuation of chambers before connecting to the fifth chamber.

[0012] In an embodiment, the plurality of pneumatic gate valves isolate the plurality of chambers from the fifth chamber to avoid cross contamination.

[0013] In an embodiment, each chamber of the plurality of chambers comprise the sample holder holding the samples mounted, wherein sample size in the sample holder ranges between 1 inch to 6 inch, and based on the substrate size, the gate valve size and the chamber design are modified.

[0014] In an embodiment, the sample holder comprising a rotator for rotating the sample during the deposition.

[0015] In an embodiment, the plurality of pneumatic gate valves operate at pressure range of $6kg/cm^2$ to $8kg/cm^2$.

[0016] In an embodiment, the measurement of the pressure inside the chambers is determined using a cold cathode Pfieffer gauge to measure high and low ranges, wherein the gauge is kept off while heating the material or deposition.

[0017] In an embodiment, the cold cathode Pfieffer gauge comprises penning gauge and pirani gauge.

[0018] In an embodiment, the chambers have been installed with at least one viewport.

[0019] In an embodiment, the chambers comprises at least four C ports, wherein three ports out of the at least four C ports are engaged with effusion cells.

[0020] In an embodiment, the effusion cells are inclined at 20^o degree from a vertical minimize loss of a material loaded into a crucible during the deposition, pointing directly towards a center of the sample holder.

[0021] In an embodiment, the effusion cells are connected to a heater, wherein temperature of the heater and stability of rate of evaporation of the heater are controlled using a proportional-integral-derivative (PID) controller.

[0022] In an embodiment, the temperature of the heater is measured through a thermocouple, wherein a maximum range of the temperature is 600 to 800 degree Celsius.

[0023] In an embodiment, the effusion cells are installed with a shutter to block evaporation of material while transferring the samples to different chambers, wherein the chambers are equipped with an orifice on the effusion cell that provides guided evaporation.

[0024] In an embodiment, the effusion cells are heated via a resistance heater.

[0025] In an embodiment, magnetic transfer arm comprises a thread as one of the arm and screwed in the substrate holder in at least four chambers and the sample is transferred to different chambers using the screws provided on the arm in four directions such as up, down, left and right.

[0026] In an embodiment, the multi-layer thin-film optoelectronic device fabricated under high vacuum ranging 3*10-6 mbar, and the high vacuum is achieved using pump station with primary pump and turbo molecular pump.

[0027] Embodiments disclosed herein provide, a method for fabricating a multi-layer thin-film optoelectronic device. The method comprises depositing a layer of optoelectronic device in high vacuum environment comprising at least four chambers of plurality of chambers and each chamber is dedicated for deposition of individual layer of the optoelectronic device and depositing one set of organic layer on the sample, in a first chamber of the plurality of chambers. Further, the method comprises the samples from one chamber to the next chamber via a fifth chamber using magnetic transfer arm and blocking evaporation of material while transferring the sample from one chamber to the

next chamber. Furthermore, the method comprises controlling stability rate of evaporation using Proportional (P), integral (I) and derivatives (D) and fabricating the optoelectronic device in high vacuum conditions without breaking the vacuum using the magnetic transfer arm.

[0028] In an embodiment, at least three chambers of the plurality of chambers are dedicated for deposition of organic layers, wherein the organic layers comprises a hole transport layer, an emissive or absorber layer (active layer) and an electron transport layer.

[0029] In an embodiment, the TMP is connected to a rotary vane pump via bellow for backing evacuation of the chambers to the high vacuum of approximately 3*10-6 mbar.

[0030] In an embodiment, the pneumatic gate valves operate at a constant line pressure 6-8 kg/cm2.

[0031] In an embodiment, the fine alignment of the magnetic transfer arm is done using the screws provided on the arm itself in all four directions.

[0032] In an embodiment, the method is fabricated under high vacuum ranging 1× 10-6 mbar, wherein the high vacuum is achieved using pump station with primary pump and turbo molecular pump.

[0033] These and other aspects of the embodiments herein will be better appreciated and understood when considered in conjunction with the following description and the accompanying drawings. It should be understood, however, that the following descriptions, while indicating preferred embodiments and numerous specific details thereof, are given by way of illustration and not of limitation. Many changes and modifications may be made within the scope of the embodiments herein without departing from the scope thereof, and the embodiments herein include all such modifications.

BRIEF DESCRIPTION OF FIGURES

[0034] This invention is illustrated in the accompanying drawings, throughout which like reference letters indicate corresponding parts in the

various figures. The embodiments herein will be better understood from the following description with reference to the drawings, in which:

[0035] FIG. 1 is a schematic illustrating a high vacuum configuration of a system for fabricating a multi-layer thin-film optoelectronic device, according to the embodiments as disclosed in system;

[0036] FIG. 2A is a schematic illustrating a top view of one of a chamber of plurality of chambers in the system for fabricating the multi-layer thin-film optoelectronic device, according to the embodiments as disclosed in system;

[0037] FIG. 2B is a schematic illustrating a side view of one of the chambers of the plurality of chambers in the system for fabricating the multi-layer thin-film optoelectronic device, according to the embodiments as disclosed in system;

[0038] FIG. 3 is a schematic illustrating a top view of a fifth central chamber of the system for fabricating the multi-layer thin-film optoelectronic device, according to the embodiments as disclosed in system;

[0039] FIG. 4 is a schematic illustrating working principle of the chamber of the plurality of chambers in the system for fabricating the multi-layer thin-film optoelectronic device, according to the embodiments as disclosed in system;

[0040] FIG. 5A is a schematic illustrating a top view of a single chamber of the system for fabricating the multi-layer thin-film optoelectronic device, according to the embodiments as disclosed in system;

[0041] FIG. 5B is a schematic illustrating a side view of the single chamber of the system for fabricating the multi-layer thin-film optoelectronic device, according to the embodiments as disclosed herein; and

[0042] FIG. 6 is a flow chart illustrating a method for fabricating the multi-layer thin film optoelectronic device, according to the embodiments as disclosed herein.

DETAILED DESCRIPTION OF INVENTION

[0043] The embodiments herein and the various features and advantageous details thereof are explained more fully with reference to the non-limiting embodiments that are illustrated in the accompanying drawings and detailed in the following description. Descriptions of well-known components and processing techniques are omitted so as to not unnecessarily obscure the embodiments herein. Also, the various embodiments described herein are not necessarily mutually exclusive, as some embodiments can be combined with one or more other embodiments to form new embodiments. The term "or" as used herein, refers to a non-exclusive or, unless otherwise indicated. The examples used herein are intended merely to facilitate an understanding of ways in which the embodiments herein can be practiced and to further enable those skilled in the art to practice the embodiments herein. Accordingly, the examples should not be construed as limiting the scope of the embodiments herein.

[0044] As is traditional in the field, embodiments may be described and illustrated in terms of blocks which carry out a described function or functions. These blocks, which may be referred to herein as units or modules or the like, are physically implemented by analog or digital circuits such as logic gates, integrated circuits, microprocessors, microcontrollers, memory circuits, passive electronic components, active electronic components, optical components, hardwired circuits and the like, and may optionally be driven by firmware. The circuits may, for example, be embodied in one or more semiconductor chips, or on substrate supports such as printed circuit boards and the like. The circuits constituting a block may be implemented by dedicated hardware, or by a processor (e.g., one or more programmed microprocessors and associated circuitry), or by a combination of dedicated hardware to perform some functions of the block and a processor to perform other functions of the block. Each block of the embodiments may be physically separated into two or more interacting and discrete blocks without departing from the scope of the

disclosure. Likewise, the blocks of the embodiments may be physically combined into more complex blocks without departing from the scope of the disclosure.

[0045] The accompanying drawings are used to help easily understand various technical features and it should be understood that the embodiments presented herein are not limited by the accompanying drawings. As such, the present disclosure should be construed to extend to any alterations, equivalents and substitutes in addition to those which are particularly set out in the accompanying drawings. Although the terms first, second, etc. may be used herein to describe various elements, these elements should not be limited by these terms. These terms are generally only used to distinguish one element from another.

[0046] In general, designing multi-chamber tool requires lot of iterations to get an optimal performance and also needs to be attached with inert gas filled glove box via load-lock design, hence larger foot print is required. Effusion cells design in commercial setups require much larger seed amount to start with for vacuum sublimation process. Further, a flexibility in design aspects is limited due to in-general a closed configuration packing. Such closed packing also results in poor debugging the faults if it occurs in system over the time of operation. Further, modification is possible based on addition of layer or scaling up the size over which thin-films need to be deposited. Customized thickness monitor sensors with line of site with respect to each effusion cell to have a controlled rate of deposition. Special design of effusion cells further reduces the cost of in general expensive organic semiconductor compounds in test runs. Samples can be transferred in inert conditions without even being attached to inert gas filled glove box with cluster tool, hence no larger foot print and allows an option to keep the two tools separately at different locations for space optimization.

[0047] Accordingly embodiments disclosed herein provide a system for fabricating a multi-layer thin film optoelectronic device comprising at least three chambers of a plurality of chambers for deposition of layers on a sample and the chamber size is expanded as per requirement. Further, the optoelectronic device comprises at least one chamber of the plurality of chambers for deposition of top electrodes and a fifth chamber for deposition of top electrodes. Furthermore, the optoelectronic device comprises the glove box is connected to the fifth chamber to remove the samples out of the fifth chamber and a Quarts Crystal Monitor (QCM) of the chambers comprises an orifice for guided evaporation. Furthermore, the optoelectronic device comprises a plurality of pneumatic gate valves for transferring the samples from one chamber to a next chamber of the plurality of chambers through the fifth chamber using magnetic transfer arms and a Turbo-molecular Pump is connected to the fifth chamber for evacuating the at least three chambers and the at least one fourth chamber. Finally, the optoelectronic device comprises a sample holder for each chamber.

[0048] The conventional tools, the glove box allows the samples to be loaded, handled, and transferred without exposure to air. A parylene deposition system is attached to the glove box cluster and the parylene is used as a dielectric material and encapsulant for organic devices. The glove box cluster features a spin coater and other equipment for solvent processing. The vacuum thermal evaporation, solvent processing and parylene coating can be performed on devices without removal from an inert atmosphere.

[0049] The conventional systems comes with a single chamber integrated inside the inert gas filled glove boxes for lab-scale research. The Effusion cells design in commercial setups require much larger seed amount to start with for vacuum sublimation process. The flexibility in design aspects is limited due to in-general a closed configuration packing. Such closed packing

also results in poor debugging the faults if the closed packing occurs in system over the time of operation.

[0050] Unlike the conventional systems, the present disclosure describes a customized tool to fabricate a multilayer thin-film optoelectronic device. Materials used in the optoelectronic device are sensitive to ambient and hence special arrangement is needed to ensure until one finish the complete fabrication, sample does not get exposed to ambient. To avoid the cross contamination a dedicated thin-film deposition chamber is provided for each layer of the device stack. Each chamber has multiple effusion cells to the vacuum evaporation/sublimation of material simultaneously with a control deposition rate as low as 0.01 A/s. After each deposition specimen gets transferred from one deposition chamber to another one via load-lock conditions without bringing the chamber in refill state. Whole of this cluster unit can be attached to an inert gas filled glove box or a special arrangement of inert atmosphere can be used at opening door of the chamber to ensure that samples remain in inert atmosphere.

[0051] Referring now to the drawings, where similar reference characters denote corresponding features consistently throughout the figures, there are shown preferred embodiments.

[0052] FIG. 1 is the schematic illustrating a high vacuum configuration of the system (100) for fabricating a multi-layer thin-film optoelectronic device, according to the embodiments as disclosed in system (100).

[0053] Referring to FIG. 1, the high vacuum system (100) configuration can also be referred as but not limited to cluster tool or a system (100). The system (100) comprise five chambers (111, 112, 113, 114, and 115). In an embodiment, the system (100) can comprise one chamber or more than one chambers (111, 112, 113, 114, and 115) and in another embodiment the system (100) comprises more than five chambers. Each chamber of the system (100) are dedicated for the deposition of layers. The layers can include but not limited

to organic layers such as hole transport layer, emissive or absorb layer (active later) and electron transport layer. One chamber is dedicated for the deposition of top electrodes that can be but not limited to metal and metal oxides or halides. The fifth chamber (115) connected to the plurality of chambers (111, 112, 113, 114) used to transfer samples from any of chambers (111, 112, 113, 114) and also termed as transfer chamber (115). In an embodiment the transfer chamber (115) can be interchangeably used as central chamber, or fifth chamber.

[0054] In an embodiment, the plurality of chambers (111-113) can be combined into one chamber comprising plurality of compartments with plurality of effusion cells (211-213) for deposition of layers. The combination of plurality of chambers into a single chamber comprising the plurality of compartments stores all organic layer with relatively less chance of cross contamination and makes the system (100) cost effective. In another embodiment, the plurality of chambers (111-113) can be independently placed with independent effusion cells (211-213).

[0055] The central chamber (115) is connected to the glove box (116) to take out the samples after deposition in inert Nitrogen atmosphere. As discussed above, out of five chambers (111, 112, 113, 114, 115) in the cluster tool, the chambers (111, 112, and 113) are for organic layers deposition. The chambers (111, 112, and 113) are similar to each other in terms of design and operation mechanism. Each chamber is evacuated via the central chamber (115) connected to the turbomolecular pump (TMP) (133). The TMP (133) is connected to the rotary vane pump (131) via bellow (132) for the backing evacuation. The combination of the rotary vane pump (131) and the TMP (133) can evacuate to the high vacuum of approximately 3*10-6 mbar. The chambers (111, 112, 113, 114 and 115) each has a sample holder (141, 142, 143, 144 and 145). Using the sample holder (141, 142, 143, 144 and 145) samples are mounted on the chambers (111, 112, 113, 114 and 115). In some embodiment, the sample holder (141, 142, 143, 144 and 145) can also be called as substrate

holder (141, 142, 143, 144 and 145). The chambers (111, 112, 113, 114), the glove box (116) and the TMP(133) each can be isolated from the central chamber (115) through gate valves (121, 122, 123, 124, 125 and 126) to avoid the cross contamination in another chamber due to material deposited in one chamber. The gate valves (121, 122, 123, 124, 125, and 126) are pneumatic gate valves (121, 122, 123, 124, 125, and 126) operate at a certain pressure range. For example, the first chamber (111) is for the deposition of a set of organic layer and the set of organic layers are transferred from one chamber to other chamber through central chamber (115) using pneumatic gate valves (121, 122, 123, 124, 125, and 126). The layers are transferred using arms attached to the substrate holder (141, 142, 143, 144 and 145). A constant line pressure 6-8 kg/cm^2 is maintained across these pneumatic gate valves. To operate any of gate valves (121, 122, 123, 124, 125 or 126) between the chambers (111, 112, 113, 114), the glove box (116), the TMP(133) and the central chamber (115), the pressure difference between the chambers (111, 112, 113, 114) should not be more than 10 mbar, otherwise the o- ring on gate valves (121, 122, 123, 124, 125, and 126) are used to seal the gate valves might get damaged. In an embodiment, a connection to nitrogen shower can also be used to protect the freshly prepared samples instead of glove box (116). For the evacuation process in the system (100), each chamber is connected to a rotary vane pump (131) for the base vacuum through the bellow (132). The central chamber (115) is connected to the TMP (133). In an embodiment, if user wants to transfer the substrate from one chamber to the next chamber, the system (100) can directly transfer using the magnetic transfer arms through the central chamber (115).

[0056] In an embodiment, the number of chambers can be at least one and can be extended to more than one as per the requirement of the optoelectronic device. Further, in another embodiment, the multiple chambers can be combined into one chamber and plurality of effusion cells are

incorporated for fabricating the multi-layer thin film optoelectronic device. As all the chambers are organic in nature the chambers contain relatively less chance of cross contamination and incorporating only one chamber makes the optoelectronic device cost effective.

[0057] FIG. 2A is the schematic illustrating the top view of one of the chamber of the plurality of chambers (111, 112, 113, 114) in the system (100) for fabricating the multi-layer thin-film optoelectronic device, according to the embodiments as disclosed in system (100). Referring to FIG. 2A, shows the top view and FIG. 2B shows the side view of the chamber (111) or any other chambers (112, 113, 114). The FIG. 2A, shows one of the four chambers of the system (100). All the chambers (111, 112, 113 and 114) are identical. Each of chambers (111, 112 and 113) has four C 40 ports. Out of four ports three are engaged with the effusion cells (211, 212, and 213). In an embodiment, the effusion cells (211, 212, and 213) can be at least 3 and can be extended to more than 3. The function principle of chambers (111, 112, and 113) are clearly described in FIG. 2 in reference with FIG. 4.

[0058] The substrate holder (141, 142, 143, 144 and 145) is also equipped with a mask plate for the deposition of structured layer. The substrate holder (141, 142, 143, 144, 145) is provided with a rotator for sample rotation to facilitate the uniform thickness of the film. For the measurement of the pressure inside the chambers (111, 112, 113, 114 and 115) each of the chambers (111, 112, 113, 114 and 115) are installed with a cold cathode Pfieffer gauge that has both penning and Pirani gauge to measure high and low vacuum range respectively. The digital display panel is installed corresponding to each pressure gauge to see the vacuum level. The Gauge is kept off while heating the material or while deposition to increase the lifetime of the Gauge.

[0059] FIG. 2B is the schematic illustrating the side view of one of the chamber of the plurality of chambers in the system (100) for fabricating the multi-layer thin-film optoelectronic device, according to the embodiments as

disclosed in system (100). Since, the fabrication of all the devices is done in high vacuum conditions, all the organic layers involved in the stack of the device are deposited without breaking vacuum. So, all the substrates are transferred from the chambers (111 to 115 to 112) without breaking vacuum. The transfer of substrates is accomplished using a magnetic transfer arm (151, 152). The magnetic arms (151, 152, 153, 154) are around 1.5 m long. One end of the arms (151, 152, 153, 154) is a thread that can be screwed in the substrate holder (141, 142, 143, 144, 145) in any of the chamber (111) and then can be transferred to the central chamber (115) and from the central chamber (115), the substrates are transferred to the one of chambers (112 or 113 and 114). The height of the sample holders (141, 142, 143 and 144) of the chambers (111, 112, 113, and 114) are aligned with the height of the sample holder (145) of the central chamber (115). Further, fine alignment of the magnetic transfer arm (151, 152, 153, 154) is done using the screws provided on the arm (151, 152, 153, 154) itself in all four directions (up, down, left and right). These transfer arms are docked on each of the chambers (111, 112, 113 and 114) through CF 40 port. As the central chamber (115) is attached to the glove box (116), so the samples can be transferred to the glove box (116) as well through transfer arm for the sample preparation, encapsulation or device characterization.

[0060] In an embodiment, the effusion cells (211, 212, and 213) points directly towards the center of the substrate holder (141, 142, 143, 144, 145). The effusion cells (211, 212, and 213) are installed with a shutter (221, 222, and 223) to block the evaporation of material while transferring the samples from any of the chambers 111, and 112, to any of the chambers 112 and 113. The effusion cells (211, 212 and 213) is equipped with an orifice that provides guided evaporation.

[0061] FIG. 3 is the schematic illustrating the top view of the central chamber (115) of the system (100) for fabricating the multi-layer thin-film optoelectronic device, according to the embodiments as disclosed in system

(100). Referring to FIG. 3, the chambers (111, 112, 113, 114), the glove box (116) and TMP (133) each can be isolated from the central chamber (115) through gate valves (121, 122, 123, 124, 125) to avoid the cross contamination in another chamber due to material deposited in one chamber. The gate valves (121, 122, 123, 124, 125, and 126) are pneumatic gate valves operate at a certain pressure range. A constant line pressure 6-8 kg/cm2 is maintained across these pneumatic gate valves (121, 122, 123, 124, 125, 126). To operate any of the gate valves (121, 122, 123, 124,125 or 126) between the chambers (111, 112, 113, 114), the glove box (116), the TMP(133) and the central chamber (115), the pressure difference between the chambers 111, 112, 113, 114, 116, 133and 115 should not be more than 10 mbar, otherwise the o- ring on the gate valves (121, 122, 123, 124, 125, and 126) which is used to seal the gate valves (121, 122, 123, 124, 125, 126) will get damage. For the measurement of the pressure inside the chamber (111, 112, 113, 114 and 115), each of the chamber (111, 112, 113, 114 and 115) is installed with the cold cathode Pfieffer gauge which has both penning and Pirani gauge to measure high and low vacuum range respectively. In an embodiment, the height of the sample holder (141, 142, 143 144) of the chambers (111, 112, 113, 114) are aligned with the height of the sample holder (145) of the central chamber (115).

[0062] FIG. 4 is the schematic illustrating working principle of the chamber of the plurality of chambers (111, 112, 113, and 114) in the system (100) for fabricating the multi-layer thin-film optoelectronic device, according to the embodiments as disclosed in system (100). The effusion cells (211, 212, and 213) in chamber (111) are inclined at 20^{o} degree from the vertical to minimize the loss of the material loaded into the crucible during the deposition. The effusion cells (211, 212, and 213) points directly towards the center of the substrate holder (141, 142, 143, 144, 145). The effusion cells (211, 212, and 213) are installed with the shutter (221, 222, and 223) to block the evaporation of material while transferring the samples from any of the chambers (111), and

the chamber (112), to any of the chamber (112) and the chamber (113). The effusion cells (211, 212 and 213) is equipped with an orifice that provides guided evaporation. The evaporation material is added to the crucible of the effusion cells (211, 212, and 213). Two types of crucibles can be used which are compatible with the system (100) of the present disclosure i.e., quartz and Alumina. Any of effusion cells (211, 212 and 213) is heated via a resistance heater (281, 282 and 283), a Nichrome wire wrap is formed like a coil in which the crucible is kept. The temperature of each crucible is individually controlled using a PID controller. The controller has options to set maximum 8 programs so that desired temperature can be reached in 8 steps for gradual heating. There are three parameters to be set in a program i.e., temperature, time, and power. The stability of rate of evaporation controlled using the parameters proportional (P), integral (I) and derivative (D). Since, each of the effusion cells (211, 212 and 213) has its own resistant heater (281, 282 and 283) and which is individually controlled using PID controller which gives freedom to use any of effusion cells (211, 212 and 213) independently resulting in the co-evaporation (maximum 3) of different molecules in each of chambers (111, 112 and 113). The temperature of each crucible is measured using a thermocouple positioned at the exit of the crucible. Typically, temperature ranges can be set from 50^{o}C to 700^{o}C depending on the sublimation temperature of the deposited material used. When the temperature of any of the effusion cells (211, 212, and 213) reaches the sublimation temperature of the material, any of the effusion cells (221, 222 and 223) is open manually, and the material leaves the crucible towards the sample holder (141). The sample holder (141) to any of the effusion cells (211, 212 and 213) distance is ~20 cm to optimize the deposition time and efficiency. Though the distance between the sample holder (141) and any of effusion cells (211, 212 and 213) is variable. The distance can be increased or decreased manually.

[0063] FIG. 5A is the schematic illustrating the top view of a single chamber of the system (100) for fabricating the multi-layer thin-film optoelectronic device, according to the embodiments as disclosed in system (100). Referring to FIG. 5A, top view and FIG. 5B shows side view of chamber (114). The chamber (114) is dedicated for the deposition of, but not limited to, metal oxides/halides/carbonates and metal top electrodes. The chamber (114) is equipped with four feed-throughs (451, 452, 453, and 454) which are connected through a common feed through (455). The feed-throughs (451, 452, 453 and 454) are separated through a metal plate to avoid mutual interaction. In chamber (114), deposition is done manually and material is added in Tungsten or Molybdenum boats (411, 412, 413, and 414). The materials are heated through the current or voltage applied in these boats. The current or voltage are applied using a Variac which goes to maximum current 10 A. In the chamber 114, 144 is equipped with a substrate rotator with a variable height.

[0064] FIG. 5B is the schematic illustrating the side view of the single chamber of the system (100) for fabricating the multi-layer thin-film optoelectronic device, according to the embodiments as disclosed herein.

[0065] In chambers (111, 112, 113 and 114) except the central chamber (115), the rate of evaporation or deposition is measured using a guided quartz crystal mounted (241, 242, 243, and 421) below the substrate shutter (231 and 431). The guided quartz crystal mount (241, 242, and 243) are helpful to measure the rate of evaporation of single material from an individual effusion cells (211, 212, and 213). The guided quartz crystal mount (241, 242 and 243) are especially very helpful in co-evaporation. The output of (241, 242, 243 and 421) is recorded in the thickness monitor STM-2 and TM-13. Before device fabrication, each layer is optimized using tooling factor provided in the thickness monitor software. When the rate of deposition is optimum, then the substrate shutter (231 or 431) can be removed manually, and material reaches

the substrate to form a thin layer fitted in the sample holder (141 or 144) which is equipped with a rotator to facilitate a uniform thickness layer.

[0066] Each of the chamber (111, 112, 113, 114 and 115) have one CF30 viewport for the ease of transferring the samples and removing the substrate shutter (231 or 431) while deposition. For the refiling of the any of the chambers (111, 112, 113, 114 and 115), there is a valve provided through a CF-16 port. The chambers (111, 112, 113, 114 and 115) are refilled through high grade nitrogen gas. Apart from the rotary vane pump (131) and the bellow (132) attached to the central chamber (115), there is a portable pump station also, that can be used for the evacuation of individual any of the chamber (111, 112, 113, and 114) before connecting to the central chamber (115). The whole cluster tool is also portable as the cluster tool is installed over a trolley.

[0067] The thin films for morphological study with thickness of around 40 nm are deposited on quartz substrates through vacuum deposition method at the rate of deposition of 1 A/s. Thin film of TPBi was also prepared to record the roughness of the films deposited in the cluster tool. The device are prepared in a sandwich geometry consisting of bottom electrode (anode), top electrode (cathode) and in between a thin layer of doped emissive layer sandwich between some transport and injection layers. The thermally activated delayed fluorescence (TADF) material based organic light emitting diode (OLED) are fabricated. The device structure can be Indium Tin Oxide ITO (150nm)/Poly(2,3-dihydrothieno-1,4-dioxin)-poly(styrenesulfonate) PEDOT:PSS(30nm)/N,N'-diphenyl-N,N'-bis(1-napthyl)-1, 10-biphenyl-4,4'-diamine NPD(30nm)/4,4'-Bis(N-carbazolyl)-1,1'-biphenyl, CBP(10nm)/CBP:2,4,5,6-Tetra(9H-carbazol-9-yl)isophthalonitrile 4CzIPN(6wt%)(15nm)/1,3,5-tris(N-phenylbenzimidazol-2-yl)benzene TPBi(30nm)/Lithium Fluoride LiF (1nm)/Alumimium Al(150nm).

[0068] Initially, the patterned ITO is cleaned with the usual ultra-sonication of the substrates in soap water, DI water, Acetone, and IPA for 10

mins and dried with the nitrogen. Then, the substrates are cleaned through plasma ashing with the oxygen plasma for 10 minutes. After the cleaning, a 30nm layer of PEDOT is deposited, PSS with a spin coating at a spin speed of 5000rpm for 45sec and annealed at 140 degree for 30 mins in nitrogen atmosphere. Then the substrates are transferred to chamber (111) for the hole transport layer deposition at the deposition rate of 1A/s, then transferred to chamber 112 for emissive layer deposition. The host was deposited at 2.8A/s, and the guest (4CzIPN) was deposited at 0.2A/s. Then the substrates are transferred to chamber 113 for electron transport layer deposition at the deposition rate of 1A/s. The depositions happened at the continuous vacuum condition (~5E-6mbar) with the uniform thickness layer deposition substrate rotation. Then the substrates are transferred to a thermal evaporator for the LiF evaporation at the deposition rate of 0.1A/s, and Al was deposited at 10A/s. For the measurement of the roughness of the films, AFM images are recorded for the 5um scan in both 2-D and 3-D view at different positions. The roughness of the film is 0.6 nm approximate all the positions on the substrate which shows the uniformity of the films deposited through the cluster tool (100). The devices are encapsulated with glass substrate using epoxy and kept for drying overnight. Under the forward bias condition, the fabricated devices with a device area of $2mm^2$ are injected with current using Keithley Sourcemeter 2400. The fabricated devices showed 21.45% external quantum efficiency for 6wt% provided they turned on at 3.5V with a current efficiency of 66.892Cd/A at the current density of 1mA/cm2. Also, the Luminance recorded for devices is 1000Cd/m2 at 1mA/cm2.

[0069] FIG. 6 is a flow chart illustrating a method for fabricating the multi-layer thin film optoelectronic device, according to the embodiments as disclosed herein

[0070] At step 1002, a layer of optoelectronic device is deposited in high vacuum environment comprising at least four chambers (111, 112, 113,

114) of a plurality of chambers, and each chamber is dedicated for deposition of individual layer of the optoelectronic device.

[0071] At step 1004, at least one set of organic layer is deposited on the sample in a first chamber of the plurality of the chambers.

[0072] At step 1006, the samples are transferred from one chamber to the next chamber via a fifth chamber (115) using magnetic transfer arm (242).

[0073] At step 1008, an evaporation of the material is blocked while transferring the sample from one chamber to the next chamber.

[0074] At step 1010, stability rate of the evaporation is controller using Proportional (P), integral (I), and deviation (D).

[0075] At step 1012, the optoelectronic device is fabricated in high vacuum conditions without breaking the vacuum using the magnetic transfer arm (242).

[0076] The various actions, acts, blocks, steps, or the like in the method may be performed in the order presented, in a different order or simultaneously. Further, in some embodiments, some of the actions, acts, blocks, steps, or the like may be omitted, added, modified, skipped, or the like without departing from the scope of the invention.

[0077] The foregoing description of the specific embodiments will so fully reveal the general nature of the embodiments herein that others can, by applying current knowledge, readily modify or adapt for various applications such specific embodiments without departing from the generic concept, and, therefore, such adaptations and modifications should and are intended to be comprehended within the meaning and range of equivalents of the disclosed embodiments. It is to be understood that the phraseology or terminology employed herein is for the purpose of description and not of limitation. Therefore, while the embodiments herein have been described in terms of preferred embodiments, those skilled in the art will recognize that the

embodiments herein can be practiced with modification within the scope of the embodiments as described herein.

CLAIMS

We Claim:

1. A system (100) for fabricating a multi-layer thin-film optoelectronic device, the system (100) comprises:

at least one chamber (111-113) of a plurality of chambers for deposition of layers on a sample, wherein a number of chambers and chamber size of the at least one chamber (111, 112, 113) are expanded as per requirements;

at least one fourth chamber (114) of the plurality of chambers for deposition of top electrodes on the sample;

a central chamber (115) of the plurality of chambers, connected to the at least one chamber (111-113) and the at least one fourth chamber (114);

a glove box (116) connected to the central chamber (115) to remove the samples out of the fifth chamber (115);

a Quartz Crystal Monitor (QCM) (241, 242, 243) of the chambers (111-114) comprises an orifice for guided evaporation;

a plurality of pneumatic gate valves (121- 126) for transferring the samples from one chamber to a next chamber of the plurality of chambers (111-114) through the central chamber (115) using magnetic transfer arms (151-154);

a turbomolecular pump (TMP) (133) connected to the fifth chamber (115) for evacuating the at least one chamber (111-113) and the at least one fourth chamber (114) and central chamber (115);and

a sample holder (141, 142, 143, 144 ,145) for each chambers (111, 112, 113, 114 ,115).

2. The system (100) as claimed in claim 1, wherein the deposition of layers comprises at least one of organic, inorganic, hybrid layers on the sample.

3. The system (100) as claimed in claim 1, wherein the deposition of the top electrodes comprises deposition of one of: metal, metal oxide, metal halides, metal carbonates.
4. The system (100) as claimed in claim 1, wherein the TMP (133) is connected to a rotary vane pump (131) via bellow (132) for backing evacuation of the chambers (111-114) to high vacuum of approximately 1*10-6 mbar.
5. The system (100) as claimed in claim 3, wherein the backing evacuation of the chambers (111-115) is performed using a portable pump station for evacuation of chambers (111-114) before connecting to the fifth chamber (115).
6. The system (100) as claimed in claim 1, wherein the plurality of pneumatic gate valves (121-126) isolate the plurality of chambers (111, 112, 113, 114, 116, 133) from the fifth chamber (115) to avoid cross contamination.
7. The system (100) as claimed in claim 1, wherein each chamber of the plurality of chambers (111, 112, 113, 114, and 115) comprise the sample holder (141-145) holding the samples mounted, wherein sample size in the sample holder (141-145) ranges between 1 inch to 6 inch, and based on the substrate size, the gate valve size and the chamber design are modified.
8. The system (100) as claimed in claim 1, wherein the sample holder (141-145) comprising a rotator for rotating the sample during the deposition.
9. The system (100) as claimed in claim 1, wherein the plurality of pneumatic gate valves (121-126) operate at pressure range of 6kg/cm^2 to 8kg/cm^2.
10. The system (100) as claimed in claim 1, wherein the measurement of the pressure inside the chambers (111-115) is determined using a cold

cathode Pfieffer gauge to measure high and low ranges, wherein the gauge is kept off while heating the material or deposition.

11. The system (100) as claimed in claim 10, wherein the cold cathode Pfieffer gauge comprises penning gauge and pirani gauge.
12. The system (100) as claimed in claim 1, wherein the chambers (111-115) have been installed with at least one viewport.
13. The system (100) as claimed in claim 1, wherein the chambers (111, 112, 113) comprises at least four C ports, wherein three ports out of the at least four C ports are engaged with effusion cells (211, 212, 213).
14. The system (100) as claimed in claim 13, wherein the effusion cells (211, 212, 213) are inclined at 20^{o} degree from a vertical minimize loss of a material loaded into a crucible during the deposition, pointing directly towards a center of the sample holder (141-145).
15. The system (100) as claimed in claim 13, wherein the effusion cells (211, 212, 213) are connected to a heater (281, 282, 283), wherein temperature of the heater and stability of rate of evaporation of the heater are controlled using a proportional-integral-derivative (PID) controller.
16. The system (100) as claimed in claim 15, wherein the temperature of the heater is measured through a thermocouple, wherein a maximum range of the temperature is 600 to 800 degree Celsius.
17. The system (100) as claimed in claim 13, wherein the effusion cells (211, 212, 213) are installed with a shutter (221, 222, 223) to block evaporation of material while transferring the samples to different chambers (111-115), wherein the chambers (111, 112, 113) are equipped with an orifice on the effusion cell that provides guided evaporation.
18. The system (100) as claimed in claim 15, wherein the effusion cells (211, 212, 213) are heated via a resistance heater (281, 282 and 283).
19. The system (100) as claimed in claim 1, the magnetic transfer arm (151-154) comprises a thread as one of the arm and screwed in the substrate

holder (141-145) in at least four chambers (111-114), wherein the sample is transferred to different chambers (111-114) using the screws provided on the arm in four directions such as up, down, left and right.

20. The system (100) as claimed in claim 1, wherein the multi-layer thin-film optoelectronic device is fabricated under high vacuum ranging 3* 10-6 mbar, wherein the high vacuum is achieved using pump station with primary pump and turbo molecular pump.

21. A method for fabricating a multi-layer thin-film optoelectronic device, wherein the method comprises:

depositing a layer of optoelectronic device in high vacuum environment comprising at least one chambers of a plurality of chambers (111-113), wherein each chamber is dedicated for deposition of individual layer of the optoelectronic device;

depositing at least one set of organic layer on a sample, in at least one chamber (111) of the plurality of chambers (111-113);

transferring, by pneumatic gate valves (121-126), the samples from one chamber to the next chamber via a fifth chamber (115) using magnetic transfer arm (151, 152, 153, 154);

blocking, by a shutter, evaporation of material while transferring the sample from one chamber to the next chamber;

controlling stability rate of evaporation using Proportional (P), integral (I) and derivative (D); and

fabricating the optoelectronic device in high vacuum conditions without breaking vacuum using the magnetic transfer arm (151, 152, 153, 154).

22. The method as claimed in claim 21, wherein the plurality of layers comprises at least one of organic, inorganic, hybrid layers on the sample.

23. The method as claimed in claim 21, wherein at least one chamber (111-113) of the plurality of chambers are dedicated for deposition of organic

layers, wherein the organic layers comprises a hole transport layer (111), an emissive or absorber layer (active layer) (112) and an electron transport layer (113).

24. The method as claimed in claim 21, wherein the TMP (133) is connected to a rotary vane pump (131) via bellow (132) for backing evacuation of the chambers (111-114) to the high vacuum of approximately 3*10-6 mbar.

25. The method as claimed in claim 21, wherein the pneumatic gate valves (121-126) operate at a constant line pressure 6-8 kg/cm^2.

26. The method as claimed in claim 21, wherein the fine alignment of the magnetic transfer arm (242) is done using the screws provided on the arm itself in all four directions.

27. The method as claimed in claim 21, wherein the method is fabricated under high vacuum ranging 1* 10-6 mbar, wherein the high vacuum is achieved using pump station with primary pump and turbo molecular pump.

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ABSTRACT

"System and Method for Fabrication of Multi-layer Thin Film Optoelectronic Devices"

In an embodiment a system (100) and method for fabrication of vacuum based optoelectronic device is disclosed. The method discloses depositing a layer of optoelectronic device in high vacuum environment comprising at least four chambers (111, 112, 113, 114) of a plurality of chambers and each chamber is dedicated for deposition of individual layer of the optoelectronic device. The method further discloses depositing set of organic layer on the sample in a first chamber (111) and to transfer the samples from one chamber to the next chamber via fifth chamber (115) using magnetic transfer arm (151). The evaporation of material are blocked while transferring the sample from one chamber to the next chamber to control the stability rate of evaporation using PID and fabricating the optoelectronic device in high vacuum conditions without breaking the vacuum using the magnetic transfer arm (151, 152).

FIG. 1