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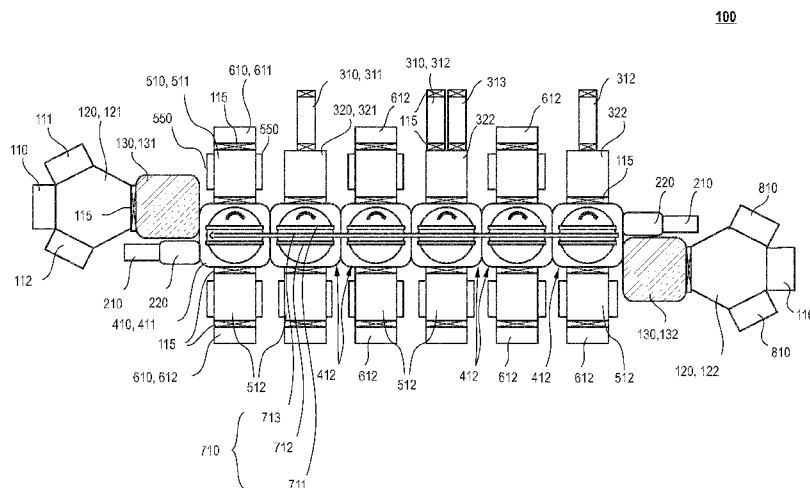


FIG. 1A

(57) Abstract: According to the present disclosure, a processing system (100) for depositing one or more layers on a substrate supported by a carrier is provided. The processing system includes: a load lock chamber (110) for loading a substrate; a routing module (410) for transporting the substrate; a first vacuum swing module (131); and a process module (510) including a deposition source for depositing material; a service module (610); an unload lock chamber (116) for unloading the substrate; a further routing module (412); a mask carrier magazine (320) configured for storing and transporting masks employed during operation of the processing system; a further vacuum swing module (132); and a transportation system (710) configured for transporting the carrier between the first vacuum swing module (131) and the further vacuum swing module (132).



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DEPOSITION SYSTEM

TECHNICAL FIELD

[0001] Embodiments of the present disclosure relate to deposition of organic material, a system for depositing materials, e.g. organic materials, a source for organic material and deposition apparatuses for organic material. Embodiments of the present disclosure particularly relate to manufacturing systems for manufacturing devices, particularly devices including organic materials therein, systems for depositing one or more layers, particularly layers including organic materials therein, on a substrate supported by a carrier, methods of manufacturing a device in a manufacturing system for manufacturing devices, particularly devices including organic materials, and methods of depositing one or more layers in a system for depositing one or more layers, particularly layers including organic materials therein, on a substrate supported by a carrier.

BACKGROUND

[0002] Organic evaporators are a tool for the production of organic light-emitting diodes (OLED). OLEDs are a special type of light-emitting diodes in which the emissive layer comprises a thin-film of certain organic compounds. Organic light emitting diodes (OLEDs) are used in the manufacture of television screens, computer monitors, mobile phones, other hand-held devices, etc. for displaying information. OLEDs can also be used for general space illumination. The range of colors, brightness, and viewing angle possible with OLED displays is greater than that of traditional LCD displays because OLED pixels directly emit light. Therefore, the energy consumption of OLED displays is considerably less than that of traditional LCD displays. Further, the fact that OLEDs can be manufactured onto flexible substrates results in further applications. A typical OLED display, for example, may include layers of organic material situated between two electrodes that are all deposited on a substrate in a manner to form a matrix display panel having individually energizable pixels. The OLED is typically placed between two glass panels, and the edges of the glass panels are sealed to encapsulate the OLED therein. Alternatively, the OLED can be encapsulated with thin film technology, e.g. with a barrier film.

[0003] There are many challenges encountered in the manufacture of such display devices. In one example, there are numerous labor intensive steps necessary to encapsulate the OLED between the two glass panels to prevent possible contamination of the device. In another example, different sizes of display screens and thus glass panels may need substantial reconfiguration of the process and process hardware used to form the display devices. Further, for masking of large area substrates, e.g. for deposition of patterned layers for the production of large scale OLED displays, a high precision is necessary in order to achieve high resolution display

[0004] Accordingly, there is a continuous need for new and improved systems, apparatuses and methods for forming devices, e.g. OLED display devices, on large area substrates at low cost and high throughput.

SUMMARY

[0005] In light of the above, a processing system for depositing one or more layers and a method for loading and unloading a substrate to a processing arrangement of a processing system are provided.

[0006] According to one aspect of the present disclosure, a processing system for depositing one or more layers, particularly layers including organic materials therein, on a substrate supported by a carrier is provided. The processing system includes: a first vacuum swing module configured for rotating a first substrate from a horizontal state into a vertical state; a first buffer chamber connected to the first vacuum swing module; a routing module connected to the first buffer chamber, wherein the routing module is configured for transporting the first substrate to a processing arrangement comprising a deposition source; a second buffer chamber connected to the routing module; and a further vacuum swing module connected to the second buffer chamber, wherein the further vacuum swing module is configured for rotating a second substrate from a vertical state into a horizontal state. The first buffer chamber is configured for buffering the first substrate received from the first vacuum swing module in a first substrate transport direction and for buffering a third substrate received from the routing module in a second substrate transport direction. The second buffer chamber is configured for buffering a second substrate received from the further vacuum swing module in the second substrate transport direction and for buffering a fourth substrate received from the routing module in the first substrate transport direction.

[0007] According to another aspect of the present disclosure, a processing system for depositing one or more layers, particularly layers including organic materials therein, on a substrate supported by a carrier is provided. The processing system includes: a load lock chamber for loading a substrate to be processed; a routing module configured for transporting the substrate supported by the carrier; a first vacuum swing module provided between the load lock chamber and the routing module; and a process module including a deposition source for depositing material in a vacuum process chamber of the process module, wherein the process module is connected to the routing module; a service module connected to the process module, wherein the service module is configured such that the deposition source can be transferred from the vacuum process chamber to the service module and from the service module to the vacuum process chamber; an unload lock chamber for unloading the substrate that has been processed; a further routing module configured for transporting the substrate supported by the carrier; a mask carrier magazine connected to the further routing module, wherein the mask carrier magazine is configured for storing and transporting masks employed during operation of the processing system; a further vacuum swing module provided between the unload lock chamber and the further routing module; and a transportation system configured for transporting the carrier between the first vacuum swing module and the further vacuum swing module under vacuum conditions and/or under a controlled inert atmosphere.

[0008] According to a further aspect of the present disclosure, a method for loading and unloading a substrate to a processing arrangement of a processing system, particularly of a processing system according to embodiments described herein, is provided. The method includes: transporting a first substrate in a first substrate transport direction from a first vacuum swing module into a first buffer chamber; buffering the first substrate and a third substrate received from a routing module in a second substrate transport direction in the first buffer chamber; shifting the first substrate and the third substrate transversal to the first substrate transport direction in the first buffer chamber; transporting the third substrate from the first buffer chamber into the first vacuum swing module; transversally back-shifting the first substrate in the first buffer chamber; transporting the first substrate in the first substrate transport direction from the first buffer chamber into the routing module; rotating the first substrate in the routing module such that the first substrate can be loaded in a loading direction into the processing arrangement connected to the routing module; loading the first substrate from the routing module into the processing arrangement; unloading a fourth substrate from the

processing arrangement into the routing module; rotating the fourth substrate in the routing module such that the fourth substrate can be transported in the first substrate transport direction from the routing module into a second buffer chamber connected to the routing module; transporting the fourth substrate in the first substrate transport direction into the second buffer chamber; shifting the fourth substrate transversal to the first substrate transport direction in the second buffer chamber; transporting a second substrate in the second substrate transport direction from a further vacuum swing module into the second buffer chamber; transversally back-shifting the fourth substrate and the second substrate in the second buffer chamber; transporting the fourth substrate from the second buffer chamber into the further vacuum swing module.

[0009] According to a yet further aspect of the present disclosure, a method for operating a processing system, particularly a processing system according to embodiments described herein, for depositing one or more layers, particularly layers including organic materials therein, on a substrate supported by a carrier, is provided. The method for operating the processing system includes: loading the substrate in the processing system in a horizontal orientation; loading the substrate onto the carrier in a vacuum swing module; rotating the carrier with the loaded substrate in a vertical orientation in the vacuum swing module; transferring the carrier with the loaded substrate through the processing system and into and out of a process module under vacuum conditions; rotating the carrier in a horizontal orientation in a further vacuum swing module; and unloading the substrate from the carrier in the further vacuum swing module in the horizontal orientation.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] So that the manner in which the above recited features of the present disclosure can be understood in detail, a more particular description of the disclosure, briefly summarized above, may be had by reference to embodiments. It is to be noted that the appended drawings illustrate only exemplary embodiments and are therefore not to be considered limiting of the scope of the present disclosure. In the drawings:

FIG. 1A shows a schematic view of a processing system having a first modular layout configuration according to embodiments described herein;

FIG. 1B shows a schematic view of a portion of a processing system having a second modular layout configuration according to embodiments described herein;

FIGS. 2A to 2H show various states of a portion of the processing system having the second modular layout configuration during loading and unloading of a substrate according to embodiments described herein;

FIG. 3A shows a schematic view of a vacuum swing module of a processing system according to embodiments described herein;

FIG. 3B shows a schematic illustration of the rotation of a carrier having a substrate supported therein in the vacuum swing module as described with respect to FIG. 2A;

FIG. 4A shows a schematic view of a process module of a processing system according to embodiments described herein;

FIGS. 4B to 4E show schematic views of a process module with a deposition source in different positions during processing of a substrate in a processing system according to embodiments described herein;

FIG. 5A shows a deposition source employed in a processing system according to embodiments described herein;

FIG. 5B shows a measurement assembly for measuring a deposition rate of a deposition source according to embodiments described herein;

FIGS. 6A to 6E show different sectional views of various embodiments of an evaporation crucible according to embodiments described herein;

FIG. 7A shows a schematic sectional view of a distribution assembly of a deposition source according to embodiments described herein;

FIGS. 7B and 7C show different detailed schematic sectional views of a distribution assembly having a shielding device according to embodiments described herein;

FIG. 7D shows a schematic perspective view of a shielding device according to embodiments described herein;

FIGS. 7E and 7F show schematic views of a nozzle of a distribution assembly according to embodiments described herein;

FIGS. 8A and 8B show different schematic perspective views of a service module of a

processing system according to embodiments described herein;

FIGS. 8C to 8E show different states of two deposition sources in a service module and a process module of a processing system according to embodiments described herein;

FIG. 9A shows a schematic perspective view of a routing module of a processing system according to embodiments described herein;

FIG. 9B shows a schematic view of two neighboring routing modules each having a process module connected thereto according to embodiments described herein;

FIGS. 10A and 10B show schematic views of a transportation apparatus for transporting a deposition source in a processing system according to embodiments described herein;

FIG. 10C shows a schematic view of a deposition source support for supporting a deposition source according to embodiments described herein;

FIGS. 11A to 11E show schematic views of various embodiments of a further transportation apparatus for transporting a carrier assembly in a processing system according to embodiments described herein;

FIG. 12A shows a schematic view of a carrier assembly and a mask employed in a processing system according to embodiments described herein;

FIG. 12B shows a schematic view of a carrier assembly including an alignment system for aligning a substrate relative to a mask in a processing system according to embodiments described herein;

FIG. 12C shows a schematic perspective view of a carrier assembly including an alignment system for aligning a substrate relative to a mask in a processing system according to embodiments described herein;

FIG. 13A shows a block diagram for illustrating a method for loading and unloading a substrate to a processing arrangement of a processing system according to embodiments described herein; and

FIG. 13B shows a block diagram for illustrating a method for operating a processing system according to embodiments described herein.

DETAILED DESCRIPTION OF EMBODIMENTS

[0011] Reference will now be made in detail to the various embodiments of the disclosure, one or more examples of which are illustrated in the figures. Within the following description of the drawings, the same reference numbers refer to same components. In the following, only the differences with respect to individual embodiments are described. Each example is provided by way of explanation of the disclosure and is not meant as a limitation of the disclosure. Further, features illustrated or described as part of one embodiment can be used on or in conjunction with other embodiments to yield yet a further embodiment. It is intended that the description includes such modifications and variations.

[0012] Embodiments described herein particularly relate to deposition of organic materials, e.g. for OLED display manufacturing and on large area substrates. According to some embodiments, large area substrates or carriers supporting one or more substrates, i.e. large area carriers, may have a size of at least 0.174 m². Typically, the size of the carrier can be about 1.4 m² to about 8 m², more typically about 2 m² to about 9 m² or even up to 12 m². Typically, the rectangular area in which the substrates are supported, for which the holding arrangements, apparatuses, and methods according to embodiments described herein are provided, are carriers having sizes for large area substrates as described herein. For instance, a large area carrier, which would correspond to an area of a single large area substrate, can be GEN 5, which corresponds to about 1.4 m² substrates (1.1 m x 1.3 m), GEN 7.5, which corresponds to about 4.29 m² substrates (1.95 m x 2.2 m), GEN 8.5, which corresponds to about 5.7m² substrates (2.2 m x 2.5 m), or even GEN 10, which corresponds to about 8.7 m² substrates (2.85 m × 3.05 m). Even larger generations such as GEN 11 and GEN 12 and corresponding substrate areas can similarly be implemented.

[0013] According to typical embodiments, which can be combined with other embodiments described herein, the substrate thickness can be from 0.1 to 1.8 mm and the holding arrangement, and particularly the holding devices, can be adapted for such substrate thicknesses. However, particularly the substrate thickness can be about 0.9 mm or below, such as 0.5 mm or 0.3 mm, and the holding arrangement, and particularly the holding devices, are adapted for such substrate thicknesses.

[0014] The term “substrate” as used herein may particularly embrace substantially inflexible substrates, e.g., a wafer, slices of transparent crystal such as sapphire or the like, or a glass plate. However, the present disclosure is not limited thereto and the term “substrate” may

also embrace flexible substrates such as a web or a foil. The term “substantially inflexible” is understood to distinguish over “flexible”. Specifically, a substantially inflexible substrate can have a certain degree of flexibility, e.g. a glass plate having a thickness of 0.5 mm or below, wherein the flexibility of the substantially inflexible substrate is small in comparison to the flexible substrates.

[0015] According to embodiments described herein, the substrate may be made of any material suitable for material deposition. For instance, the substrate may be made of a material selected from the group consisting of glass (for instance soda-lime glass, borosilicate glass etc.), metal, polymer, ceramic, compound materials, carbon fiber materials or any other material or combination of materials which can be coated by a deposition process.

[0016] FIG. 1A shows a processing system 100 for manufacturing devices, particularly devices including organic materials therein. For example, the devices can be electronic devices or semiconductor devices, such as optoelectronic devices and particularly displays. In particular, the processing system as described herein is configured for improved carrier handling and/or mask handling during layer deposition on a substrate. These improvements can be beneficially utilized for OLED device manufacturing. However, the improvements in carrier handling and/or mask handling, which is provided by the concepts of arrangement of various system modules as described herein (also referred to as chambers), may also be utilized for other substrate processing systems, for example substrates processing systems including evaporation sources, sputter sources, particularly rotary sputter targets, CVD deposition sources, such as PECVD deposition sources, or combinations thereof. The embodiments of the present disclosure relate to manufacturing systems, particularly for processing large area substrates is described with respect to OLED manufacturing systems, as these OLED manufacturing systems may particularly benefit from the concepts described herein.

[0017] More specifically, the processing system 100 as described herein is configured for conducting an evaporation deposition method. The evaporation deposition method is based on the principle that a coating material evaporates in a vacuum controlled environment and condenses on a cold surface. To achieve a sufficient evaporation without reaching the boiling point of the evaporation material, the evaporation process is carried out in a vacuum environment. The principle of the evaporation deposition typically includes three phases: The first phase is the evaporating phase in which the material to be evaporated is heated in a crucible to an operating temperature. The operating temperature is set to create sufficient vapor pressure to move material from the crucible to the substrate. The second phase is the transport

phase in which the vapor is moved from the crucible through, for example, a steam distribution pipe with nozzles onto a substrate for providing an even layer of the vapor onto the substrate. The third phase is the condensation phase in which the surface of the substrate has a lower temperature than the evaporated material which allows the vaporized material to adhere to the substrate.

[0018] With exemplary reference to FIG. 1A, according to embodiments which can be combined with other embodiments described herein, the processing system may include a vacuum swing module 130; a substrate carrier module 220; a routing module 410; a process module 510; a service module 610; a mask carrier loader 310; a mask carrier magazine 320; and a transportation system 710. Typically, a substrate carrier loader 210 in which the substrate carriers to be used are stored is connected to the substrate carrier module 220. Similarly, the mask carrier magazine 320 is configured to store masks which are intended to be used during processing of the substrate. According to some embodiments, the routing modules of the processing system may be connected directly to each other, as exemplary shown in FIG. 1A. Alternatively, neighboring routing modules of the processing system may be connected via a transfer module 415, as exemplarily shown in FIG. 1B. In other words, typically a transfer module 415 including a vacuum transfer chamber may be installed between neighboring routing modules. Accordingly, typically the transfer module is configured to provide vacuum conditions inside the vacuum transfer chamber. Further, as schematically indicated in FIG. 1B, the transportation system 710, particularly a transportation apparatus for contactless levitation and transportation of a carrier assembly as described in more detail with reference to FIGS. 11A to 11D, can be provided in the transfer module 415. Further, the transfer module 415 may include a gate valve for a cryo-pump, a connecting flange for the cryo-pump and a connecting flange, also referred to as transfer flange herein, for connecting a routing module. Typically, the transfer flange includes a frame and sealing surface adapted to provide a vacuum tight connection to a process module to be connected. According to some embodiments, the transfer module 415 may include an access door configured for providing access to the interior of the transfer module, e.g. for maintenance services.

[0019] With exemplary reference to FIGS. 1A and 1B, the processing system as described herein may be used for the production of display devices, particularly OLEDs. According to embodiments which can be combined with any other embodiment described herein, the processing system 100 is such that the processing of a substrate can be conducted under vacuum conditions. The substrate is loaded in the vacuum swing module 130, particularly the

first vacuum swing module 131. The mask and substrate carrier loader stores all of the carriers (e.g. mask carriers and substrate carriers, respectively) that can be used in the processing system. The routing module 410 sends the mask and substrate carriers in the applicable process module. After processing, the substrate can be unloaded from the processing system by a further vacuum swing module 132. Alternatively, the substrate can be loaded to and unloaded from the processing system by the same vacuum swing module, e.g. the first vacuum swing module 131. Accordingly, the substrate, particularly the substrate carrier with the substrate, may be transported on a loop track to return the substrate for unloading to the same vacuum swing module which has been used for loading the substrate to the processing system.

[0020] More specifically, with exemplary reference to FIG. 1A, according to some embodiments the processing system 100 may include a load lock chamber 110, which is connected to a first substrate handling chamber 121. The substrate can be transferred from the first substrate handling chamber 121 to the first vacuum swing module 131, wherein the substrate is loaded in a horizontal position on a carrier. After loading the substrate on the carrier in the horizontal position, the first vacuum swing module 131 rotates the carrier having the substrate provided thereon in a vertical or essentially vertical orientation. The carrier having the substrate provided thereon is then transferred through a first routing module 411 and a further routing module 412 for transferring the vertically orientated substrate to a process module 510. For example, in FIG. 1 six routing modules and ten process modules are shown.

[0021] With exemplary reference to FIG.1A, according to embodiments which can be combined with any other embodiment described herein, a first pretreatment chamber 111 and a second pretreatment chamber 112 may be provided. Further, a robot (not shown) or another handling system can be provided in the substrate handling chamber 120. The robot or the another handling system can load the substrate from the load lock chamber 110 in the substrate handling chamber 120 and transfer the substrate into one or more of the pretreatment chambers. For example, the pretreatment chambers can include a pretreatment tool selected from the group consisting of: plasma pretreatment of the substrate, cleaning of the substrate, UV and/or ozone treatment of the substrate, ion source treatment of the substrate, RF or microwave plasma treatment of the substrate, and combinations thereof. After pretreatment of the substrates, the robot or another handling system may transfer the substrate out of the pretreatment chamber via the substrate handling chamber into the vacuum swing module 130.

[0022] In order to allow for venting the load lock chamber 110 for loading of the substrates and/or for handling of the substrate in the substrate handling chamber 120 under atmospheric

conditions, at least one gate valve can be provided between the substrate handling chamber 120 and the vacuum swing module 130. Accordingly, the substrate handling chamber 120, and if desired one or more of the load lock chamber 110, the first pretreatment chamber 111 and the second pretreatment chamber 112, can be evacuated before the gate valve 115 is opened and the substrate is transferred into the first vacuum swing module 131. Accordingly, loading, treatment and processing of substrates may be conducted under atmospheric conditions before the substrate is loaded into the first vacuum swing module 131.

[0023] According to embodiments, typically the process module 510 can be connected to a routing module 410. For example, as exemplarily shown in FIG. 1A, ten process modules may be provided each being connected to one of the routing modules. Particularly, the process module 510 may be connected to a routing module 410, e.g. via a gate valve 115. A gate valve 115 as described herein may also be referred to as a lock valve. According to embodiments described herein, a gate valve or a lock valve can be used to separate the individual processing system modules (also referred to as processing system chambers) from each other. Accordingly, the processing system as described herein is configured such that the vacuum pressure in the individual processing system chambers can be controlled and changed separately and independently from each other.

[0024] According to some embodiments, the processing system can further include a layer inspection chamber (not shown). For example, a layer inspection tool, such as an electron and/or ion layer inspection tool, can be provided in a layer inspection chamber. For instance, layer inspection can be conducted after one or more deposition actions or processing actions provided in the processing system. Accordingly, typically the layer inspection chamber may be connected to the process module or the routing module as described herein. For example, the processing system may be configured such that a carrier having a substrate therein can be moved from a process module to a layer inspection chamber. Accordingly, the processing system as described herein can be configured such that the substrate to be inspected can be inspected within the processing system, i.e. without removing the substrate from the processing system. Accordingly, beneficially the processing system as described herein may be configured for online layer inspection which may be conducted after one or more of the deposition actions or processing actions.

[0025] According to some embodiments, and as shown in FIG. 1A, one or more routing modules (also referred to as rotation modules herein) are provided along a line for providing an in-line transportation system for transporting the substrate from one process module to another

process module. Typically, as exemplarily shown in FIG. 1A, a transportation system 710 is provided in the processing system 100. The transportation system 710 is configured for transporting and transferring a substrate to be processed, typically supported by a carrier assembly, between the individual modules or chambers of the processing system 100. For instance, the transportation system 710 may include a first transportation track 711 and a second transportation track 712 along which carriers for supporting substrates or masks may be transported. In particular, the transportation system 710 may include at least one transportation apparatus for contactless levitation and transportation as described in more detail with reference to FIGS. 11A to 11E.

[0026] According to some embodiments, which can be combined with other embodiments described herein, the transportation system 710 may include a further track 713 provided within the two or more routing modules as exemplarily shown in FIG. 1A. In particular, the further track 713 may be a carrier return track.

[0027] Typically, the carrier return track can be provided between the first transportation track 711 and second transportation track 712. The carrier return track allows for returning empty carriers from the further vacuum swing module 132 to the first vacuum swing module 131, as exemplarily shown in FIG. 1A. Accordingly, it is to be understood that the empty carriers may be returned under vacuum conditions. Returning the carriers under vacuum conditions and, optionally, under controlled inert atmosphere (e.g. Ar, N₂ or combinations thereof) reduces the carriers' exposure to ambient air. Contact to moisture can be reduced or avoided. Thus, the outgassing of the carriers during manufacturing of the devices in the manufacturing system can be reduced. This may improve the quality of the manufactured devices and/or the carriers can be in operation without being cleaned for an extended time.

[0028] With exemplary reference to FIG. 1A, according to embodiments which can be combined with any other embodiment described herein, an alignment system 550 can be provided at the process module 510, particularly at the vacuum process chamber 540. Further details of the process module 510 are, for example, described with reference to FIGS. 4A to 4E and further details of the alignment system 550 are described with respect to FIGS. 12B and 12C.

[0029] According to typical embodiments, the service module 610 (also referred to as maintenance module herein) can be connected to the process module 510, for example via a gate valve 115. Typically, the processing system include two or more service modules, e.g. a

first service module 611 and at least one second service module 612. As described herein, the service module allows for maintenance of deposition sources in the processing system. Further details of the service module are described with respect to FIGS. 8A-8E.

[0030] According to embodiments which can be combined with other embodiments described herein, the processing system can include a substrate carrier loader 210 and a substrate carrier module 220, as exemplarily shown in FIGS. 1A and 1B. For example, the substrate carrier module 220 may be configured to buffer one or more substrate carriers. For example, the substrate carrier module 220 may be connected to the first routing module 411 which is connected to the first vacuum swing module 131. Additionally or alternatively, a substrate carrier module and a substrate carrier loader may be connected to the last routing module, for example the sixth routing module shown in Fig. 1A. Accordingly, typically a substrate carrier module 220 may be connected to one of the routing modules, which is connected to one of the vacuum swing modules. Since the substrates are loaded and unloaded in the vacuum swing modules, it is beneficial to provide the substrate carrier module close to a vacuum swing module. Typically, the substrate carrier module 220 is configured to provide storage for one or more, for example 5 to 30, substrate carriers. Accordingly, beneficially embodiments of the deposition as described herein are configured such that substrate carriers may be replaced, for example for maintenance, such as cleaning.

[0031] With exemplarily reference to FIGS. 1A and 1B, according to embodiments which can be combined with other embodiments described herein, the processing system 100 may include a mask carrier loader 310, e.g. a first mask carrier loader 311 and a second mask carrier loader 312, and a mask carrier magazine 320 for buffering various masks. In particular, the mask carrier magazine 320 may be configured to provide storage for replacement masks and/or masks which need to be stored for specific deposition processes. Accordingly, a mask employed in the processing system can be exchanged either for maintenance, such as cleaning, or for a variation of deposition pattern. Typically, the mask carrier magazine 320 may be connected to a routing module, e.g. to one of the further routing modules shown in FIG. 1A, for example via a gate valve 115. Accordingly, a mask can be exchanged without venting the vacuum process chamber and/or the routing module such that exposing the mask to atmospheric pressure can be avoided.

[0032] According to embodiments which can be combined with other embodiments described herein, a mask cleaning chamber 313 may be connected to the mask carrier magazine 320, e.g. via a gate valve 115, as exemplarily shown in FIG. 1A. For instance, a plasma

cleaning tool can be provided in the mask cleaning chamber 313. Additionally or alternatively, a further gate valve 115 can be provided at the mask cleaning chamber 313, as shown in FIG. 1A, through which a cleaned mask may be unloaded from the processing system 100. Accordingly, a mask can be unloaded from the processing system 100 while only the mask cleaning chamber 313 needs to be vented. By unloading the mask from the manufacturing system, an external mask cleaning can be provided while the manufacturing system continues to be fully operating. FIG. 1A illustrates the mask cleaning chamber 313 adjacent to the mask carrier magazine 320. A corresponding or similar cleaning chamber (not shown) may also be provided adjacent to the substrate carrier module 220. By providing a cleaning chamber adjacent to the substrate carrier module 220, substrate carriers may be cleaned within the processing system.

[0033] After processing of the substrate, the substrate carrier having the substrate thereon is transferred from the last routing module into a further vacuum swing module 132 in the vertical orientation. The further vacuum swing module 132 is configured to rotate the carrier having the substrate thereon from the vertical orientation to a horizontal orientation. Thereafter, the substrate can be unloaded into a further horizontal substrate handling chamber. The processed substrate may be unloaded from the processing system 100 through a load lock chamber 110. Additionally or alternatively, the processed substrate can be encapsulated in a thin-film encapsulation chamber 810 which can be connected to the further vacuum swing module 132, as exemplarily shown in FIG. 1A. The one or more thin-film encapsulation chambers may include an encapsulation apparatus, wherein the deposited and/or processed layers, particularly an OLED material, are encapsulated between, i.e. sandwiched between, the processed substrate and a further substrate in order to protect the deposited and/or processed material from being exposed to ambient air and/or atmospheric conditions. However, other encapsulation methods like lamination with glass, polymer or metal sheets, or laser fusing of a cover glass may alternatively be applied by an encapsulation apparatus provided in one of the thin-film encapsulation chambers.

[0034] According to embodiments which can be combined with any other embodiment described herein, several mask carriers and substrate carriers can be moved through the processing system at the same time. Typically, the movement of the mask carriers and the substrate carriers is coordinated with the sequence tact times. The tact time may depend on the process and the module type. For example, the routing module may be configured for providing a rotation time from 90° to 180° of 5 seconds. Further, the processing system may be

configured such that the substrate transportation between two neighboring modules is typically 5 seconds without the gate valve movement (i.e. opening/closing of the gate valve). The processing system, particularly the alignment system of the processing system, may be configured such that the substrate mask alignment process including all alignment actions can be carried out within 25 seconds. Further, the processing system may be configured such that a release from an aligner and a magnet plate after processing, e.g. coating, is 10 seconds. According to typical embodiments, the swing module is configured to load the substrate within 10 seconds. Further, the substrate carrier module may be configured to align and chuck the substrate within 10 seconds. Typically, the swing module may be configured to move the swing from the horizontal position to the vertical position within 10 seconds. According to typical embodiments, the transportation system is configured to provide a short linear move of approximately 100 mm within 5 seconds. The process module may be configured to perform the processing method, for example a coating method, within 60 seconds with 3 seconds source rotation to complete the pass. It is to be understood that the processing rate (e.g. the deposition rate) and the processing speed (e.g. the speed with which the deposition source moves over the substrate) can be adjusted in order to control the processing result, e.g. the thickness of a coating.

[0035] Accordingly, a device such as an OLED display can be manufactured in the processing system 100 as exemplarily shown in FIGS. 1A and 1B as follows. The substrate can be loaded into the first substrate handling chamber 121 via a load lock chamber 110. A substrate pretreatment can be provided within the first pretreatment chamber 111 and/or the second pretreatment chamber 112 before the substrate is loaded in the first vacuum swing module 131. The substrate is loaded on a substrate carrier in the first vacuum swing module 131 and rotated from a horizontal orientation to a vertical orientation. Thereafter, the substrate is transferred through the first routing module 411 and one or more further routing modules. The routing modules are configured to rotate the substrate carrier with the substrate thereon such that the carrier with the substrate can be moved to a neighboring process module 510, as exemplarily indicated in FIG. 1A. For example, in the first process module 511 an electrode deposition can be conducted in order to deposit the anode of the device on the substrate. Thereafter, the carrier with the substrate can be removed from the first process module 511 and moved to one of the further process modules 512 which are connected to the routing modules. For example, one or more of the further process modules may be configured to deposit a hole injection layer, one or more of the further process modules may be configured to deposit a blue emission layer, a green emission layer or a red emission layer, one or more of the further

process modules may be configured to deposit an electron transportation layer which is typically provided between the emission layers and/or above the emission layers. At the end of the manufacturing, a cathode can be deposited in one of the further process modules. Additionally, one or more exciton blocking layers (or hole blocking layers) or one or more electron injection layers may be deposited between the anode and the cathode in one of the further process modules. After deposition of all desired layers, the carrier is transferred to the further vacuum swing module 132, wherein the carrier with the substrate is rotated from the vertical orientation to a horizontal orientation. Thereafter, the substrate is unloaded from the carrier in the further substrate handling chamber 122 and can be transferred to one of the thin-film encapsulation chambers 810 for encapsulating the deposited layer stack. Thereafter, the substrate with the manufactured device can be unloaded from the processing system through an unload lock chamber 116.

[0036] With exemplary reference to FIG. 1B, according to embodiments which can be combined with other embodiments described herein, the processing system may be configured such that the loading and unloading of the substrate can be carried out on the same side of the processing system, particularly by employing two vacuum swing modules on the same side, as exemplarily described in more detail with reference to FIGS. 2A to 2H. In particular, with exemplary reference to FIG. 1B, according to some embodiments which can be combined with any other embodiments described herein, the processing system 100 for depositing one or more layers may include a first vacuum swing module 131, a first buffer chamber 151, a routing module 410, e.g. a first routing module 411, a second buffer chamber 152, a further vacuum swing module 132, and a processing arrangement 1000.

[0037] More specifically, with exemplary reference to FIGS. 1B and 2A to 2H, the first vacuum swing module 131 is configured for rotating a first substrate 101A from a horizontal state into a vertical state. The first buffer chamber 151 is connected to the first vacuum swing module 131. The first buffer chamber 151 is configured for buffering the first substrate 101A received from the first vacuum swing module 131 in a first substrate transport direction 106. Further, the first buffer chamber 151 is configured for buffering a third substrate 101C received from the routing module 410 in a second substrate transport direction 107. The routing module 410, particularly the first routing module 411, is connected to the first buffer chamber 151, and is configured for transporting the first substrate 101A to the processing arrangement 1000. The processing arrangement 1000 typically includes at least one deposition source as described herein. Further, the second buffer chamber 152 is connected to the routing module 410,

particularly to the first routing module 411. The second buffer chamber 152 is configured for buffering a second substrate 101B received from the further vacuum swing module 132 in the second substrate transport direction 107. Further, the second buffer chamber 152 is configured for buffering a fourth substrate 101D received from the routing module 410, particularly from the first routing module 411, in the first substrate transport direction 106. As exemplarily shown in FIG. 2D, the further vacuum swing module 132 is connected to the second buffer chamber 152 and is configured for rotating the second substrate 101B from a vertical state into a horizontal state.

[0038] In the present disclosure, a “buffer chamber” may be understood as a chamber which is configured to buffer two or more substrates, particularly two or more substrates supported by a substrate carrier, in a vertical orientation. More specifically, a “buffer chamber” as described herein can be a vacuum chamber configured for providing vacuum conditions inside the buffer chamber.

[0039] According to embodiments which can be combined with any other embodiments described herein, the processing arrangement 1000 may include a further routing module 412 as described herein and a process module 510 as described herein. Further, the processing arrangement 1000 may include a service module 610 according to embodiments described herein. According to some embodiments, the processing arrangement 1000 may further include at least one of the group consisting of: a mask carrier magazine 320 as described herein; a mask carrier loader 310 as described herein; a transportation apparatus 720 for contactless transportation of a deposition source as described herein, a further transportation apparatus 820 for contactless levitation, transportation and/or alignment of a carrier assembly as described herein; an alignment system 550 as described herein; a mask cleaning chamber 133 as described herein; and a layer inspection chamber. Accordingly, it is to be understood that the processing arrangement 1000 described with respect to FIGS. 1B and 2A-2H may include some or all processing modules and processing components as described with respect to FIGS. 1A and FIGS. 3A to 12C. For instance, in the layout configuration in which the loading and unloading of the substrate can be carried out on the same side of the processing system of a load lock chamber 110 as described herein; an unload lock chamber 116 as described herein; a first pretreatment chamber 111 and/or a second pretreatment chamber 112 as described herein; and an encapsulation chamber 810 as described herein may be provided.

[0040] With exemplary reference to FIGS. 2A to 2H, according to embodiments which can be combined with any other embodiments described herein, the first buffer chamber 151 may

include a first switch track 161 configured for shifting a substrate, e.g. the first substrate 101A and/or the third substrate 101C, transversal to the first substrate transport direction 106. Similarly, the second buffer chamber 152 may include a second switch track 162 configured for shifting a substrate, e.g. the second substrate 101B and/or the fourth substrate 101D transversal to the second substrate transport direction 107. Typically, in the first substrate transport direction 106 is opposite to the second substrate transport direction 107, as exemplarily shown in FIGS 2A to 2H.

[0041] In the present disclosure, a “switch track” may be understood as a track arrangement having two or more parallel tracks which are configured for receiving two or more substrates, particularly two or more substrates supported by a substrate carrier, in a vertical orientation. More specifically, a “switch track” as described herein can be understood as a track arrangement which is configured such that two or more vertical substrates can be shifted substantially perpendicular to the surface to the substrate, which may correspond to a shifting direction which is substantially perpendicular to the substrate transport direction in which the two or more substrates are received by the track arrangement.

[0042] According to embodiments which can be combined with any other embodiments described herein, the routing module 410, e.g. the first routing module 411 as shown in FIGS. 1B and 2A to 2E, can be configured to rotate the first substrate 101A received from the first buffer chamber 151 such that the first substrate can be loaded into the processing arrangement 1000 in a loading direction which is different from the first substrate transport direction 106. Typically, the loading direction is perpendicular to the first substrate transport direction. Further, as exemplarily described with reference to FIG. 2D, the routing module 410, particularly the first routing module 411, is configured to receive the fourth substrate 101D from the processing arrangement 1000 in an unloading direction which is different from the loading direction. Typically, in the processing system layout in which the loading and unloading can be carried out on the same side of the processing system, as exemplarily shown in FIGS. 1B and 2A to 2E, the loading direction is opposite to the unloading direction.

[0043] As exemplarily shown in FIGS. 1B and 2A to 2H, gate valves 115 may be provided between the first vacuum swing module 131 and the first buffer chamber 151, between the first buffer chamber 151 and the routing module 410 (e.g. the first routing module 411), between the routing module 410 and processing arrangement 1000, between the routing module 410 and the second buffer chamber 152, and between the second buffer chamber 152 and the further vacuum swing module 132.

[0044] Accordingly, the processing system having a layout configuration as described with reference to FIGS. 1B and 2A to 2E beneficially provide for an improved method for loading and unloading a substrate to a processing arrangement of a processing system as described herein such that the tact time for loading and unloading a substrate to the processing arrangement can be reduced. FIG. 13 A shows a block diagram for illustrating a method 1100 for loading and unloading a substrate to a processing arrangement of a processing system according to embodiments described herein.

[0045] In particular, with exemplarily reference to FIGS. 2A to 2H and 13A, the method 1100 for loading and unloading a substrate to a processing arrangement includes: transporting a first substrate 101A in a first substrate transport direction 106 from a first vacuum swing module 131 into a first buffer chamber 151 (represented by block 1110 in FIG. 13A); buffering the first substrate 101A and a third substrate 101C received from a routing module 410 in a second substrate transport direction 107 in the first buffer chamber 151 (represented by block 1120 in FIG. 13A); shifting the first substrate 101A and the third substrate 101C transversal to the first substrate transport direction 106 in the first buffer chamber 151 (represented by block 1130 in FIG. 13A); transporting the third substrate 101C from the first buffer chamber 151 into the first vacuum swing module 131 (represented by block 1140 in FIG. 13A); transversally back-shifting the first substrate 101A in the first buffer chamber 151 (represented by block 1150 in FIG. 13A); transporting the first substrate 101A in the first substrate transport direction 106 from the first buffer chamber 151 into the routing module 410 (represented by block 1160 in FIG. 13A); rotating the first substrate 101A in the routing module 410 such that the first substrate 101A can be loaded in a loading direction into the processing arrangement 1000 connected to the routing module 410 (represented by block 1170 in FIG. 13A); loading the first substrate 101A from the routing module 410 into the processing arrangement 1000 (represented by block 1180 in FIG. 13A); unloading a fourth substrate 101D from the processing arrangement 1000 into the routing module 410 (represented by block 1190 in FIG. 13A); rotating the fourth substrate 101D in the routing module 410 such that the fourth substrate 101D can be transported in the first substrate transport direction 106 from the routing module 410 into a second buffer chamber 152 connected to the routing module 410 (represented by block 1200 in FIG. 13A); transporting the fourth substrate 101D in the first substrate transport direction 106 into the second buffer chamber 152 (represented by block 1210 in FIG. 13A); shifting the fourth substrate 101D transversal to the first substrate transport direction 106 in the second buffer chamber 152 (represented by block 1220 in FIG. 13A); transporting a second substrate 101B in the second substrate transport direction 107 from a further vacuum swing

module 132 into the second buffer chamber 152 (represented by block 1230 in FIG. 13A); transversally back-shifting the fourth substrate 101D and the second substrate in the second buffer chamber 152 (represented by block 1240 in FIG. 13A); transporting the fourth substrate 101D from the second buffer chamber 152 into the further vacuum swing module 132 (represented by block 1250 in FIG. 13A).

[0046] FIG. 2A shows a state during loading of a substrate to the processing arrangement 1000 in which a first substrate 101A, e.g. an unprocessed substrate, is transported in a first substrate transport direction 106 from a first vacuum swing module 131 into a first buffer chamber 151. In the first buffer chamber 151, a third substrate 101C, e.g. a processed substrate, received from a routing module 410 in a second substrate transport direction 107 is buffered on a first track of the first switch track 161. Accordingly, after the first substrate 101A has been transported to the first buffer chamber 151, particularly to the second track of the first switch track 161, the first substrate 101A and the third substrate 101C are buffered in the first buffer chamber 151. Typically, the first buffer chamber 151 and the first switch track 161 are configured for buffering and transporting at least two substrates in a vertical substrate orientation as described herein. In FIGS. 2A to 2H, the third substrate 101C and the fourth substrate 101D are processed substrates, which is indicated by the hatching. Accordingly, the first substrate 101A and the second substrate 101B in FIGS. 2A to 2H are unprocessed substrates, e.g. new substrates.

[0047] Subsequently, as exemplarily indicated by the vertical arrow in FIG. 2B, the first substrate 101A and the third substrate 101C can be shifted transversal to the first substrate transport direction 106 in the first buffer chamber 151. Typically, shifting the first substrate 101A and the third substrate 101C transversal to the first substrate transport direction 106 is conducted by the first switch track 161. As indicated by the horizontal arrow in FIG. 2B, after the first substrate 101A and the third substrate 101C have been shifted, the third substrate 101C can be transported from the first buffer chamber 151 into the first vacuum swing module 131 in the second substrate transport direction 107.

[0048] Thereafter, as indicated by the vertical arrow in FIG. 2C, the first substrate 101A in the first buffer chamber 151 is transversally back-shifted, particularly by back shifting by the first switch track 161. Further, as indicated by the bowed arrow on the left side of FIG. 2C, the third substrate 101C may be rotated from the vertical state into a horizontal state. As indicated by the horizontal arrow in FIG. 2C, the first substrate 101A may be transported in the first substrate transport direction 106 from the first buffer chamber 151 into the routing module 410.

[0049] With exemplary reference to FIG. 2D, after the first substrate 101A has been transported into the routing module 410, the first substrate 101A may be rotated in the routing module 410 such that the first substrate 101A can be loaded in a loading direction into the processing arrangement 1000 connected to the routing module 410. Accordingly, thereafter the first substrate 101A can be loaded from the routing module 410 into the processing arrangement 1000 as indicated by the vertical arrow pointing upwards in FIG. 2D. Further, as indicated by the vertical arrow pointing downwards in FIG. 2D, a fourth substrate may be unloaded from the processing arrangement 1000 into the routing module 410. Additionally, as indicated by the horizontal arrow at the first vacuum swing module 131, the horizontal third substrate may be removed from the first vacuum swing module 131. Moreover, as indicated by the bowed arrow on the right side of the further vacuum swing module 132, a second substrate 101B provided in a horizontal state in the second swing module may be rotated into a vertical state.

[0050] In the following, when the first substrate has been loaded into the processing arrangement 1000 and the fourth substrate has been unloaded from the processing arrangement 1000 into the routing module 410, the fourth substrate 101D may be rotated in the routing module 410 such that the fourth substrate 101D can be transported in the first substrate transport direction 106 from the routing module 410 into the second buffer chamber 152 connected to the routing module 410, as exemplarily indicated in FIG. 2E. Meanwhile, as exemplarily shown in FIG. 2E, a new substrate 101N may be loaded in a horizontal state into the first vacuum swing module 131. Further, the first switch track 161 and/or the second switch track 162 may be shifted transversal to the substrate transport direction, as indicated by the vertical arrows in FIG. 2E.

[0051] As exemplarily shown in FIG. 2F, the fourth substrate 101D may then be transported in the first substrate transport direction 106 from the routing module 410 into the second buffer chamber 152. Subsequently; the fourth substrate 101D may be shifted transversal to the first substrate transport direction 106 in the second buffer chamber 152 as exemplarily indicated by the vertical arrow pointing downwards in FIG. 2G. Accordingly, the second switch track 162 in the second buffer chamber 152 is positioned such that a second substrate 101B can be transported in the second substrate transport direction 107 from the further vacuum swing module 132 into the second buffer chamber 152. Typically, the second buffer chamber 152 and the second switch track 162 are configured for buffering and transporting at least two substrates in a vertical substrate orientation as described herein. Further, as indicated by the bowed arrow

on the left side of the first vacuum swing module 131, in the meantime the new substrate 101N may be rotated from the horizontal state into the vertical state for subsequently loading the new substrate into the first buffer chamber 151.

[0052] As exemplarily indicated by the vertical arrow pointing upwards in FIG. 2H, after the second substrate 101B has been received in the second buffer chamber 152, the fourth substrate 101D and the second substrate 101B are transversally back-shifted in the second buffer chamber 152 such that the fourth substrate 101D can be transported from the second buffer chamber 152 into the further vacuum swing module 132. In the following, the fourth substrate may then be rotated from the vertical state into a horizontal state inside the further vacuum swing module 132 such that the fourth substrate can then be unloaded from the further vacuum swing module 132 in the horizontal state.

[0053] Accordingly, by providing a processing system layout in which the loading and unloading of the substrate can be carried out on the same side of the processing system as exemplarily described with reference to FIGS. 1B and 2A to 2H, a carrier return track for empty carriers may be omitted. Thus, beneficially the tact times, the throughput and the efficiency of the processing system can be improved.

[0054] In view of the embodiments of the processing system described herein, it is to be understood that the modular configuration of the processing system provides for the possibility to adapt the processing system to customer needs. For example, the processing system may be configured for OLED production, e.g. as single layer and/or multi-layers. In particular, the number of process modules employed may be selected dependent on the complexity of the device which is intended to be produced by using the processing system according to embodiments described herein. Further, the processing system layout can be adapted to the customer's spatial and logistic boundary conditions.

[0055] In FIG. 3A, a schematic view of a vacuum swing module 130, e.g. of the first vacuum swing module 131 or the further vacuum swing module 132, of a processing system 100 according to embodiments described herein is shown. According to embodiments which can be combined with other embodiments described herein, the vacuum swing module 130 includes a vacuum swing chamber 133. The vacuum swing chamber typically has one or more flanges for connecting an evacuation unit, for example a vacuum pump, to the vacuum swing chamber. Accordingly, the vacuum swing chamber 133 can be evacuated to a technical vacuum, e.g. of 10 mbar or below, which can be provided in one or more modules or chambers

of the processing system described herein. Further, as exemplarily shown in FIG. 3A, typically the vacuum swing module 130 includes a base 137. The base 137 is configured to provide stability while the substrate 101, which is loaded on a substrate carrier 910, is supported in the vertical orientation or horizontal orientation. The latter orientation is shown in FIG. 3A.

[0056] Further, the vacuum swing module 130 may be provided with an actuator 135, for example a torque motor, which is configured to rotate the support 134 around a rotation axis 136. The rotatable support may also be referred to as swing station herein. Accordingly, the support and/or a table connected thereto can be rotated from the horizontal orientation to a vertical orientation and vice versa. In light of the above, the substrate 101 can be loaded on a substrate carrier 910 while the support is provided having a horizontal orientation. In particular, the substrate 101 may be moved into the vacuum swing module 130 through a substrate entrance opening 138, as exemplarily shown in FIG. 3A. Typically, the substrate entrance opening 138 is configured such that the substrate can be moved into the vacuum swing module in a horizontal state. Thereafter, the substrate carrier 910 supporting the substrate 101 can be rotated from the horizontal orientation into a vertical orientation and moved along a transportation path into a first routing module and out of the first vacuum swing module 131, for example through a substantially vertically orientated exit opening 139, as indicated in the dotted lines in FIG. 3A.

[0057] Accordingly, after processing of the substrate in a substantially vertical state, the substrate carrier with the processed substrate thereon can be moved out of a routing module into the further vacuum swing module 132, as exemplarily shown in the FIGS. 1A and 1B. In the further vacuum swing module 132, the substrate carrier 910 supporting the substrate 101 can be rotated from the vertical orientation to a horizontal orientation. Thereafter, the substrate 101 can be unloaded from the substrate carrier 910. Accordingly, it is to be understood that a vacuum swing module as described herein may be used for loading and/or unloading the substrate for processing the substrate in the processing system.

[0058] Typically, a vacuum swing module as described herein is configured for being under high-vacuum conditions. Accordingly, the vacuum swing module may be provided with at least one gate valve such that a substrate carrier may be moved into and out of the vacuum swing module without breaking the vacuum in the vacuum swing chamber. Further, the vacuum swing station may be provided with an electrostatic chuck which is configured for holding the substrate to the swing station, e.g. the rotatable support. For transferring the substrate from the swing station to the substrate carrier, the substrate is released from the

electrostatic chuck of the swing station while an electrostatic chuck of a substrate carrier is positioned for receiving and holding the substrate.

[0059] FIG. 3B illustrates a sequence of rotating the substrate 101 provided in a substrate carrier 910 from a horizontal orientation in a vertical orientation or vice versa. From left to right, the substrate 101 is provided in the substrate carrier 910. Lift pins 140 can be provided below the substrate carrier 910 such that the substrate 101 is raised or lowered relative to the substrate carrier 910 upon the vertical movement of the lift pins 140. The carrier typically includes a substrate receiving portion, an upper guiding portion 911, and a lower guiding portion. The upper guiding portion can include one or more passive magnetic elements to allow for magnetic guiding of the carrier, as exemplarily described in more detail with reference to FIGS. 11A and 11B.

[0060] Before the substrate 101 is loaded on the substrate carrier 910, the lift pins 140 are moved vertically to a raised position. A robot or another actuator can load the substrate in the vacuum swing module and place the substrate onto the lift pins 140. Accordingly, the lift pins 140 are configured to support the substrate 101. Thereafter, the lift pins can be lowered, such that the substrate 101 is loaded onto the substrate carrier 910. Thereafter, the substrate carrier 910 can be rotated as shown by the sequence of FIG. 3B, while, for example, a rod of the substrate carrier 910 is located in one or more rollers 912 of the transportation system. Alternatively, the lower guiding portion of the substrate carrier may be provided with one or more rollers which may be configured to guide the substrate carrier on a corresponding transportation track. Further, particularly the upper guiding portion of the substrate carrier may include a first passive magnetic element 851 and the lower guiding portion of substrate carrier may include a second passive magnetic element 852, as exemplarily described with reference to FIGS. 11C to 11E. Accordingly, after the substrate carrier has been raised to a vertical position, the substrate carrier can be moved along the transportation path of the processing system, particularly along a guiding structure, e.g. of the transportation apparatus for contactless transportation of the carrier as described in more detail with reference to FIGS. 11A and 11B.

[0061] FIG. 4A illustrates an embodiment of a process module 510 for a processing system according to embodiments described herein, e.g. for depositing organic material. Typically, a deposition source 520, particularly an evaporation source, is provided in a vacuum process chamber 540 of the process module 510. In particular, the deposition source 520 can be provided on a track or linear guide 522, as exemplarily shown in FIG. 4A. The linear guide 522 may be configured for the translational movement of the deposition source 520. Further, a drive

for providing a translational movement of deposition source 520 can be provided. In particular, as described in more detail with reference to FIGS. 10A to 10 C, a transportation apparatus 720 for contactless transportation of the deposition source may be provided in the vacuum process chamber 540. As exemplarily shown in FIG. 4A, the vacuum process chamber 540 may have gate valves 115 via which the vacuum process chamber can be connected to an adjacent routing module or an adjacent service module, as exemplarily shown in FIGS. 1A and 1B. In particular, the gate valves allow for a vacuum seal to an adjacent vacuum chamber and can be opened and closed for moving a substrate and/or a mask into or out of the process module.

[0062] In the present disclosure, a “vacuum process chamber” is to be understood as a vacuum chamber or a vacuum deposition chamber. The term “vacuum”, as used herein, can be understood in the sense of a technical vacuum having a vacuum pressure of less than, for example, 10 mbar. Typically, the pressure in a vacuum chamber as described herein may be between 10^{-5} mbar and about 10^{-8} mbar, more typically between 10^{-5} mbar and 10^{-7} mbar, and even more typically between about 10^{-6} mbar and about 10^{-7} mbar. According to some embodiments, the pressure in the vacuum chamber may be considered to be either the partial pressure of the evaporated material within the vacuum chamber or the total pressure (which may approximately be the same when only the evaporated material is present as a component to be deposited in the vacuum chamber). In some embodiments, the total pressure in the vacuum chamber may range from about 10^{-4} mbar to about 10^{-7} mbar, especially in the case that a second component besides the evaporated material is present in the vacuum chamber (such as a gas or the like).

[0063] The processing system can include one or more vacuum pumps, such as turbo pumps and/or cryo-pumps, connected to the vacuum chamber for generation of the vacuum inside the vacuum chamber. Further, according to some embodiments, fore-vacuum pumps may be provided, e.g. for generating a fore-vacuum in a vacuum chamber of the processing system as described herein. Further, fore-vacuum may be provided to pump the exhaust outlets for high-vacuum pumps, i.e. the turbo pumps and/or cryo-pumps.

[0064] With exemplary reference to FIG. 4A, according to embodiments which can be combined with any other embodiment described herein, two substrates, e.g. a first substrate 101A and a second substrate 101B can be supported on respective transportation tracks within the vacuum process chamber 540. Further, two tracks for providing masks 330 thereon can be provided. In particular, the tracks for transportation of a substrate carrier and/or a mask carrier may be provided with a further transportation apparatus for contactless transportation of the

carriers as described in more detail with reference to FIGS. 11A to 11B.

[0065] Typically, coating of the substrates may include masking the substrates by respective masks, e.g. by an edge exclusion mask as exemplarily described with reference to FIG. 12A or by a shadow mask as exemplarily described with reference to FIG. 12B. According to typical embodiments, the masks, e.g. a first mask 330A corresponding to a first substrate 101A and a second mask 330B corresponding to a second substrate 101B, are provided in a mask frame 331 to hold the mask in a predetermined position, as exemplarily shown in FIG. 4A.

[0066] According to some embodiments, which can be combined with other embodiments described herein, the substrate 101 can be supported by a substrate support 102, which can be connected to an alignment system 550, e.g. by connecting elements 124. An alignment system 550 can adjust the position of the substrate 101 with respect to the mask 330. Accordingly, the substrate can be moved relative to the mask 330 in order to provide for a proper alignment between the substrate and the mask during deposition of the organic material. According to a further embodiment, which can be combined with other embodiments described herein, alternatively or additionally the mask 330 and/or the mask frame 331 holding the mask 330 can be connected to the alignment system 550. Accordingly, either the mask can be positioned relative to the substrate 101 or the mask 330 and the substrate 101 can both be positioned relative to each other. Accordingly, as described in more detail with reference to FIGS. 12 B and 12C, an alignment system as described herein allows for a proper alignment of the masking during the deposition process, which is beneficial for high quality or LED display manufacturing.

[0067] Examples of an alignment of a mask and a substrate relative to each other include alignment units, which allow for a relative alignment in at least two directions defining a plane, which is essentially parallel to the plane of the substrate and the plane of the mask. For example, an alignment can at least be conducted in an x-direction and a y-direction, i.e. two Cartesian directions defining the above-described parallel plane. Typically, the mask and the substrate can be essentially parallel to each other. Specifically, the alignment can further be conducted in a direction essentially perpendicular to the plane of the substrate and the plane of the mask. Thus, an alignment unit is configured at least for an X-Y-alignment, and specifically for an X-Y-Z-alignment of the mask and the substrate relative to each other. One specific example, which can be combined with other embodiments described herein, is to align the substrate in x-direction, y-direction and z-direction to a mask, which can be held stationary

in the vacuum process chamber.

[0068] As shown in FIG. 4A, the linear guide 522 provides a direction of the translational movement of the deposition source 520. On both sides of the deposition source 520, a mask 330, e.g. a first mask 330A for masking a first substrate 101A and second mask 330B for masking a second substrate 101B can be provided. The masks can extend essentially parallel to the direction of the translational movement of the deposition source 520. Further, the substrates at the opposing sides of the evaporation source can also extend essentially parallel to the direction of the translational movement. According to typical embodiments, a substrate 101 can be moved into the vacuum process chamber 540 and out of the vacuum process chamber 540 through a gate valve 115. Accordingly, the process module 510 can include a respective transportation track for transportation of each of the substrates, e.g. a first transportation track for the first substrate and a second transportation track for the second substrate. Typically, the transportation track extends parallel to the substrate orientation.

[0069] According to embodiments which can be combined with any other embodiment described herein, further tracks can be provided for supporting the mask frames holding the masks. Accordingly, four tracks may be provided within the vacuum process chamber. In order to move one of the masks out of the vacuum process chamber, for example for cleaning of the mask, the mask frame with the mask can be moved onto the transportation track of the substrate. The respective mask frame can then exit or enter the vacuum process chamber on the transportation track for the substrate. Even though it would be possible to provide a separate transportation track into and out of the vacuum chamber for the mask frames, the costs of ownership of a process module can be reduced if only two tracks, i.e. transportation tracks for a substrate, extend into and out of the vacuum process chamber and, in addition, the mask frames can be moved onto a respective one of the transportation tracks for the substrate by an appropriate actuator or robot.

[0070] With exemplary reference to FIG. 4A, a source support 531 configured for the translational movement of the deposition source 520 along the linear guide 522 may be provided. Typically, the source support 531 supports an evaporation crucible 521 and a distribution assembly 530 provided over the evaporation crucible 521. Accordingly, the vapor generated in the evaporation crucible can move upwardly and out of the one or more outlets of the distribution assembly. Accordingly, the distribution assembly 530 is configured for providing evaporated organic material, particularly a plume 318 of evaporated source material, from the distribution assembly 530 to the substrate 101, as exemplarily illustrated in FIGS. 4B

to 4E.

[0071] The one or more outlets can be one or more openings or one or more nozzles, which can, e.g., be provided in a showerhead or another vapor distribution system. A showerhead can be understood herein to include an enclosure having openings such that the pressure in the showerhead is higher than outside of the showerhead, for example by at least one order of magnitude. Details with respect to the evaporation crucible and the distribution assembly employed in a deposition system as described herein are described with reference to FIGS. 6A to 6D and FIGS. 5A, 7A-7C, respectively.

[0072] Further, according to embodiments which can be combined with other embodiments described herein, the deposition source may include a shielding device 517 as shown in FIG. 4A and described in more detail with reference to FIGS. 7A to 7D. Additionally, a material collection unit 40 may be provided which can be configured as a shielding wall, as exemplarily shown in FIG. 4A. The material collection unit 40 may be arranged in the vacuum process chamber to collect evaporated source material emitted from the deposition source, e.g. an evaporation source, when the deposition source is in a rotated position as exemplarily shown in FIG. 4D. As exemplarily shown in FIG. 4A, a heating device 50 may be provided for cleaning the shaper shielding device 517 in a service position of the deposition source. The service position may be a position of the deposition source in which the outlets of a distribution assembly as described herein are in a rotated position as compared to a deposition position of the distribution assembly in which the outlets are directed towards a substrate to be coated.

[0073] According to embodiments which can be combined with other embodiments described herein, the rotation of the distribution assembly can be provided by a rotation of an evaporator control housing, on which at least the distribution assembly is mounted. Typically, also the evaporation crucible is mounted on the evaporator control housing. Accordingly, the deposition source may be configured such that at least the distribution assembly is rotatably mounted or such that both the crucible and the distribution assembly are together rotatably mounted. Alternatively, the control housing, distribution assembly and the evaporation crucible may be rotatably mounted together. Typically, the material collection unit is mounted fixedly, such that the material collection unit does not rotate together with the distribution assembly and remains stationary with respect to the rotation of the distribution assembly. Yet, as exemplarily shown in FIGS. 4B to 4E, the material collection unit follows the translational movement and is moveable with respect to the translational movement.

[0074] FIGS. 4B to 4E show a deposition source 520, particularly an evaporation source, in various positions in a vacuum process chamber 540. The movement between the different positions is indicated by arrows 102B, 102C, and 102D. In FIG. 4B, the deposition source 520 is shown in a first position. As shown in FIG. 4C, the left substrate in the vacuum process chamber 540 is deposited with a layer of organic material by a translational movement of the deposition source as indicated by arrow 102B. While the left substrate, e.g. a first substrate 101A, is deposited with the layer of organic material, a second substrate 101B, e.g. the substrate on the right-hand side in FIGS. 4B to 4E, can be exchanged, as indicated by the dotted lines. After the first substrate 101A has been deposited with a layer of organic material, the distribution assembly 530 of the deposition source 520 can be rotated as indicated by arrow 102C in FIG. 4D. During deposition of the organic material on the first substrate 101A, the second substrate 101B has been positioned and aligned with respect to the second mask 330B. Accordingly, after the rotation shown in FIG. 4D, the second substrate 101B can be coated with a layer of organic material by a translational movement of the deposition source as indicated by arrow 102D. While the second substrate 101B is coated with the organic material, the first substrate 101A can be moved out of the vacuum process chamber 540, as indicated by the dotted lines.

[0075] Accordingly, by providing a processing system including two or more process modules according to embodiments described herein, different layers may be deposited on a substrate inside the process modules, e.g. by evaporating processes of inter alia organic material for OLED production. As exemplarily outlined above with reference to FIGS. 4A to 4E, each process module of the two or more process modules typically has two process sides. At the inside of each process side, typically magnetic levitation rails are provided that move the mask carrier and substrate carrier into the process position, as described in more detail with reference to FIGS. 11A to 11E. At the outside of each process side, an alignment system configured for aligning the substrate relative to the mask is provided. Typically, the process module is configured such that the mask carrier can be moved into the process position and is held in place with locking bolts. Then the substrate carrier is moved into the process position and the alignment system performs the alignment of the substrate and the mask.

[0076] FIG. 5A shows a perspective view of a deposition source 520 according to embodiments described herein. As exemplarily shown in FIG. 4A, the deposition source 520 may include a distribution assembly 530 which is connected to an evaporation crucible 521. For example, that distribution assembly 530 may include a distribution pipe which can be an

elongated cube. For instance, a distribution pipe as described herein may provide a line source with a plurality of openings and/or nozzles which are arranged in at least one line along the length of the distribution pipe. Alternatively, one elongated opening extending along the at least one line can be provided. For example, the elongated opening can be a slit. According to some embodiments, which can be combined with other embodiments described herein, the line may essentially be vertical.

[0077] Accordingly, the distribution assembly may include a distribution pipe which is provided as a linear distribution showerhead, for example, having a plurality of openings disposed therein. A showerhead as understood herein has an enclosure, hollow space, or pipe, in which the material can be provided or guided, for example from the evaporation crucible. The showerhead can have a plurality of openings (or an elongated slit) such that the pressure within the showerhead is higher than outside of the showerhead. For example, the pressure within the showerhead can be at least one order of magnitude higher than outside the showerhead.

[0078] Further, as exemplarily shown in FIG. 5A, the distribution assembly typically provides a line source extending essentially vertically. In the present disclosure, the term “essentially vertically” is understood particularly when referring to the substrate orientation, to allow for a deviation from the vertical direction of 10° or below. This deviation can be provided because a substrate support with some deviation from the vertical orientation might result in a more stable substrate position. Yet, the substrate orientation during deposition of the organic material is considered essentially vertical, which is considered different from the horizontal substrate orientation. Accordingly, the surface of the substrates can be coated by a line source extending in one direction corresponding to one substrate dimension and a translational movement along the other direction corresponding to the other substrate dimension.

[0079] According to embodiments which can be combined with any other embodiments described herein, the length of the distribution pipe may correspond at least to the height of the substrate to be deposited. In particular, the length of the distribution pipe may be longer than the height of the substrate to be deposited, at least by 10% or even 20%. For example, the length of the distribution pipe can be 1.3 m or above, for example 2.5 m or above. Accordingly, a uniform deposition at the upper end of the substrate and/or the lower end of the substrate can be provided. According to an alternative configuration, the distribution assembly may include one or more point sources which can be arranged along a vertical axis.

[0080] According to embodiments which can be combined with other embodiments described herein, the evaporation crucible 521 is in fluid communication with distribution assembly 530 and provided at the lower end of the distribution assembly 530, as exemplarily shown in FIG. 5B. In particular, a connector, e.g. a flange unit may be provided, which is configured to provide a connection between the evaporation crucible 521 and the distribution assembly 530. For example, the evaporation crucible and the distribution assembly may be provided as separate units, which can be separated and connected or assembled at the connector, e.g. for operation of the evaporation source. Typically, the evaporation crucible is a reservoir for the organic material to be evaporated by heating the crucible. Accordingly, the evaporated organic material may enter the distribution assembly, particularly at the bottom of the distribution pipe, and is guided essentially sidewardly through the plurality of openings in the distribution pipe, e.g. towards an essentially vertical substrate.

[0081] As exemplarily shown in FIG. 5A, the distribution assembly 530 may be designed in a triangular shape. A triangular shape of the distribution assembly 530 may be beneficial in case two or more distribution pipes may be arranged next to each other, as exemplarily described in more detail with reference to FIGS. 7A and 7B. In particular, a triangular shape of the distribution assembly 530 makes it possible to bring the outlets of neighboring distribution pipes as close as possible to each other. This allows for achieving an improved mixture of different materials from different distribution pipes, e.g. for the case of the co-evaporation of two, three or even more different materials.

[0082] According to embodiments, which can be combined with other embodiments described herein, the distribution assembly 530 may include walls, for example side walls 525B and a wall at the backside 525A of the distribution assembly 530 such that an inner hollow space is provided inside the distribution assembly. As exemplarily shown in FIG. 4A, a heating unit 515 may be provided for heating the distribution assembly, particularly the distribution pipes. The heating unit 515 may be mounted or attached to the walls of the distribution assembly 530. Accordingly, the distribution assembly 530 can be heated to a temperature such that the vapor of the organic material, which is provided by the evaporation crucible 521, does not condense at an inner portion of the wall of the distribution assembly 530. Further, a heat shield may be provided around the tube of the distribution assembly, particularly the distribution pipe, to reflect heat energy provided by the heating unit 515 back towards the hollow space.

[0083] The heat shield can include several shielding layers to reduce the heat radiation to

the outside of the evaporation source. As a further option, the heat shield may include shielding layers which are actively cooled by a fluid, such as air, nitrogen, water or other appropriate cooling fluids. According to yet further embodiments, which can be combined with other embodiments described herein, one or more heat shields may be provided for the evaporation source which can include sheet metals surrounding the respective portions of the evaporation source. For example, the sheet metals can have a thicknesses of 0.1 mm to 3 mm, can be selected from at least one material selected from the group consisting of ferrous metals (SS) and non-ferrous metals (Cu, Ti, Al), and/or can be spaced with respect to each other, for example by a gap of 0.1 mm or more. Accordingly, the distribution assembly as described herein is configured such that the energy employed to heat the distribution can be reduced because heat losses can be minimized.

[0084] According to some embodiments, which can be combined with other embodiments described herein, the deposition source 520 may include a shielding device, particularly a shaper shielding device 517, to delimit the distribution cone of evaporated material provided to a substrate. Further, the shielding device may be configured to reduce the heat radiation towards the deposition area. Further, the shield may be cooled by a cooling element 516. For example, the cooling element 516 may be mounted to the backside of the shaper shielding device 517 and may include a conduit for cooling fluid.

[0085] In some implementations, the deposition source can be configured for a rotation around an axis, particularly during evaporation. Accordingly, a rotation drive may be provided, for example at the connections between the source cart and the deposition source, which is configured for turning the evaporation source parallel to the substrate before the deposition of the substrate is carried out. Various applications for OLED device manufacturing include processes where two or more organic materials are evaporated simultaneously. Accordingly, in some embodiments, two or more distribution assemblies, particularly distribution pipes and corresponding evaporation crucibles can be provided next to each other. Such an evaporation source may also be referred to as an evaporation source array, e.g. wherein more than one kind of organic material is evaporated at the same time. An example of an evaporation source array is described with reference to FIGS. 7A and 7B.

[0086] Further, with exemplary reference to FIG. 5A, according to embodiments which can be combined with any other embodiment described herein, a deposition rate measurement assembly 580 may be provided. In particular, the deposition rate measurement assembly 580 may be provided at an upper end of the distribution assembly behind a measurement outlet 535

of the distribution assembly 530. As exemplarily indicated by the arrow exiting the measurement outlet 535 in FIG. 4A, the measurement outlet 535 may be configured for providing evaporated material from the inside of the distribution assembly 530 through the measurement outlet 535 to the deposition rate measurement assembly 580.

[0087] With exemplary reference to FIG. 5B, the deposition rate measurement assembly 580 may include an oscillation crystal 581 for measuring the deposition rate and a holder 582 for holding the oscillation crystal 581. The holder 582 may include a material having a thermal conductivity k above $k=30 \text{ W/(mK)}$, particularly, above $k=50 \text{ W/(mK)}$, more particularly above $k=70 \text{ W/(mK)}$, for example above $k=150 \text{ W/(mK)}$. For example, the holder 582 may be a solid body including at least one material selected from the group consisting of: copper, aluminum, copper alloy, aluminum alloy, brass, iron, silver, silver alloy, gold alloy, magnesium, wolfram, silicon carbide, aluminum nitride, or other suitable materials. Accordingly, thermal effects on the oscillation crystal which can decrease the measurement accuracy may be reduced.

[0088] Typically, the oscillation crystal 581 is arranged inside the holder 582 having a measurement opening 583. In particular, the oscillation crystal may be in close contact with the solid body of the holder, such that heat may be transferred from the oscillation crystal to the holder. As exemplarily shown in FIG. 5B, the measurement opening 583 may be configured and arranged such that evaporated material may be deposited on the oscillation crystal for measuring the deposition rate of the evaporated material.

[0089] According to an alternative configuration (not explicitly shown) of the deposition rate measurement assembly, which can be combined with other embodiments described herein, the deposition rate measurement assembly can include a first oscillation crystal for measuring the deposition rate, a second oscillation crystal for measuring the deposition rate, and a movable shutter. The movable shutter is configured for blocking the evaporated material provided from a first measurement outlet, wherein the first measurement outlet is directed for providing evaporated material to the first oscillation crystal, and wherein the movable shutter is configured for blocking the evaporated material provided from a second measurement outlet, wherein the second measurement outlet is directed for providing evaporated material to the second oscillation crystal.

[0090] According to embodiments which can be combined with other embodiments described herein, the movable shutter of the alternative configuration of the deposition rate

measurement assembly is a rotatable element, particularly a rotatable disk, having at least one aperture. The at least one aperture is configured for providing access for the evaporated material provided from the first measurement outlet to the first oscillation crystal when the rotatable element is in a first state.

[0091] According to embodiments which can be combined with other embodiments described herein, the at least one aperture of the alternative configuration of the deposition rate measurement assembly is configured for providing access for the evaporated material provided from the second measurement outlet to the second oscillation crystal when the rotatable element is in a second state.

[0092] According to embodiments which can be combined with other embodiments described herein, the at least one aperture of the alternative configuration of the deposition rate measurement assembly includes a first aperture and a second aperture which are arranged diametrically opposed to each other.

[0093] According to embodiments which can be combined with other embodiments described herein, the at least one aperture of the alternative configuration of the deposition rate measurement assembly includes a third aperture and a fourth aperture which are arranged on opposing sides of the first aperture and/or the second aperture. Typically, the third aperture and the fourth aperture are arranged at a radial position substantially corresponding to a radial position of the first aperture and/or a radial position of the second aperture.

[0094] According to embodiments which can be combined with other embodiments described herein, the alternative configuration of the deposition rate measurement assembly further comprises a heater configured for applying heat to the first oscillation crystal and/or the second oscillation crystal, such that material deposited on the first oscillation crystal and/or the second oscillation crystal can be evaporated.

[0095] According to embodiments which can be combined with other embodiments described herein, the alternative configuration of the deposition rate measurement assembly further comprises a further heater provided in the movable shutter configured for applying heat to the movable shutter such that material deposited on the movable shutter can be evaporated.

[0096] According to embodiments which can be combined with other embodiments described herein, the heater of the alternative configuration of the deposition rate measurement assembly is provided in a first holder for the first oscillation crystal and a second holder of the

second oscillation crystal.

[0097] In the present disclosure, an “oscillation crystal” may be understood as an oscillation crystal which is configured for measuring a mass variation of deposited material on the oscillation crystal per unit area by measuring the change in frequency of an oscillation crystal resonator. In particular, in the present disclosure an oscillation crystal may be understood as a quartz crystal resonator. More particularly, an “oscillation crystal for measuring the deposition rate” may be understood as a quartz crystal microbalance (QCM).

[0098] As exemplarily shown in FIG. 5B, according to embodiments which can be combined with other embodiments described herein, a heat exchanger 584 may be arranged in the holder 582, for example next to or adjacent to the oscillation crystal 581. The heat exchanger 584 may be configured to exchange heat with the oscillation crystal and/or with the holder 582. For example, the heat exchanger may include tubes through which a cooling fluid may be provided. The cooling fluid may be a liquid, e.g. water, or a gas, e.g. air. In particular, the cooling fluid may be chilled compressed air. According to embodiments which can be combined with other embodiments described herein, the heat exchanger 584 may be configured for cooling the holder 582 and/or the oscillation crystal 581 to a temperature of 15°C or below, particularly 10°C or below (e.g. 8°C or below). Accordingly, negative effects of high temperature on the quality, accuracy and stability of the deposition rate measurement may be reduced or even eliminated. In particular, by providing a measurement assembly as described herein, thermal fluctuations of the oscillation crystal may be reduced or even eliminated, which may be beneficial for the deposition rate measurement accuracy.

[0099] With exemplary reference to FIG. 5B, according to some embodiments which can be combined with other embodiments described herein, a temperature sensor 585 may be provided which can be arranged and configured for measuring the temperature of the holder 582 and or the oscillation crystal 581. Accordingly, information about the temperature, e.g. the absolute temperature or temperature fluctuations, of the deposition rate measurement assembly may be obtained such that a critical temperature at which the oscillation crystal tends to measure inaccurately may be detected. Accordingly, in the case that a critical absolute temperature or critical temperature fluctuation of the measurement assembly is detected, particularly of the holder and/or of the oscillation crystal, by the temperature sensor, an adequate reaction may be initiated, for example cooling by employing the heat exchanger as described herein, which may be beneficial for the deposition rate measurement accuracy.

[00100] According to embodiments which can be combined with other embodiments described herein, the deposition rate measurement assembly 580 may include a temperature control system 586 for controlling the temperature of the oscillation crystal 581 and/or of the holder 582. In particular, the temperature control system 586 may include one or more of a temperature sensor 585, a heat exchanger 584 and a controller 575. As exemplarily shown in FIG. 5B, the controller 575 may be connected to the temperature sensor 585 for receiving data measured by the temperature sensor 585. Further, the controller 575 may be connected to the heat exchanger 584 for controlling the temperature of the holder 582 and/or the oscillation crystal 581. Accordingly, the controller may be configured for controlling the temperature of the holder 582 and/or oscillation crystal 581 dependent on the temperature measured by the temperature sensor 585. For example, in the case that the temperature sensor 585 detects a critical temperature at which the oscillation crystal tends to measure inaccurately, the controller may initiate a control signal to the heat exchanger 584 for cooling the holder 582 and/or the oscillation crystal 581. Accordingly, in the case that an ideal measurement temperature of the oscillation crystal, for example below 15°C, particularly below 10°C, more particularly below 5°C is detected by the temperature sensor 585, a previously initiated cooling may be stopped by sending a corresponding control signal to the heat exchanger such that the cooling may be stopped.

[00101] With exemplary reference to FIG. 5B, according to embodiments which can be combined with other embodiments described herein, the deposition rate measurement assembly 580 may include a shutter 587 for blocking the evaporated material provided from a measurement outlet 535. In particular, the shutter 587 may be configured to be movable from a first state of the shutter into a second state of the shutter, as exemplarily indicated by the arrow in FIG. 5B. For example, the first state of the shutter may be an open state in which the shutter 587 does not block the measurement outlet 535 and the second state of the shutter 587 may be a state in which the shutter 587 blocks the measurement outlet 535 such that the oscillation crystal 581 is protected from evaporated material provided through the measurement outlet 535, as exemplarily shown in FIG. 5B. Accordingly, the oscillation crystal and/or the holder may be protected from high temperature of the evaporated material in a situation in which the deposition rate has not to be measured.

[00102] Further, the shutter 587 may include a thermal protection shield 588 for protecting the oscillation crystal 581 and/or the holder 582 from the heat of the evaporated material provided through the measurement outlet 535. Additionally or alternatively, the shutter 587

may include a shutter cooling element 589. As exemplarily shown in FIG. 5B, the thermal protection shield 588 may be arranged on a side of the shutter 587 which faces the measurement outlet 535. In particular, the thermal protection shield 588 may be configured for reflecting heat energy provided by evaporated material provided through the measurement outlet 535. For example, the thermal protection shield 588 may be a plate, e.g. a sheet metal, or include two or more plates, e.g. two or more metal sheets which may be spaced with respect to each other, for example by a gap of 0.1 mm or more. For example, the sheet metal may have a thickness of 0.1 mm to 3.0 mm. In particular, the thermal protection shield may include a ferrous or non-ferrous material, for example at least one material selected from the group consisting of copper (Cu), aluminum (Al), copper alloy, aluminum alloy, brass, iron, titanium (Ti), ceramic and other suitable materials.

[00103] FIG. 6A illustrates an exemplary embodiment of an evaporation crucible 521, including a wall with an inner surface surrounding an inner volume 560 for receiving a source material, e.g. an organic material. For example, the volume of evaporation crucible can be between 100 cm³ and 3000 cm³, particularly between 700 cm³ and 1700 cm³, more particularly 1200 cm³. The crucible shown in Fig. 6A is illustrated as two halves, which are mirror symmetrical with respect to a plane of symmetry 501. Typically, the evaporation crucible 521 may include a connector 524 via which the crucible and the distribution assembly, particularly a distribution pipe, may be connected to each other, e.g. by a form-fit connection. The evaporation crucible 521 may include a bottom wall 557 and a top wall 558. The bottom wall and top wall may be connected to each other via side walls 561-566. Accordingly, the inner volume 560 of the evaporation crucible 521 may be enclosed by the bottom wall 557, the top wall 558 and the side walls 561-566. According to embodiments of the crucible, at least the top wall 558 may include a crucible opening 504 which allows evaporated source material to exit from the crucible and enter the distribution assembly, e.g. a distribution pipe, which is configured to guide the evaporated source material to a substrate.

[00104] According to the embodiment shown in Fig. 6A, a crucible heating unit 523 may be provided at or in the wall of the evaporation crucible 521. For example, the heating unit may include one or more heaters. The crucible heating unit may extend at least along a portion of the wall of the crucible. According to some implementations herein, the evaporation crucible 521 may further include a crucible shield 527 which may be configured to reflect heat energy provided by the crucible heating unit 523 back towards the enclosure of the crucible. Accordingly, the shield crucible may support an efficient heating of the source material within

the inner volume of the evaporation crucible.

[00105] According to embodiments, the evaporation crucible 521 may include one or more heat transfer elements 570 arranged within the inner volume 560 of the evaporation crucible 521. The heat transfer elements 570 may be configured to provide an indirect heating of the inner volume of the crucible. Accordingly, the heat from the one or more heat transfer elements may be directly provided to the source material, which may be in the form of powders, liquids and/or pellets, within the inner volume of the crucible. For example, the heat transfer elements can be configured to receive heat passively and may not need a direct connection to, for instance, a heating unit and/or power supply. In particular, the heat transfer elements 570 may, for instance, receive heat from the crucible wall and/or from the outside of the crucible. Accordingly, during a deposition process, the heat from the wall and/or from the outside of the crucible is distributed within the inner volume of the crucible by the heat transfer elements to ensure a more homogenous heating and subsequent evaporation of the source material. In particular, the heat transfer elements may be arranged within the inner volume of the crucible such that the temperature measured at any specific location within the inner volume of the crucible compared to a predetermined temperature and/or compared to the temperature at another specific location within the inner volume of the crucible differs by a maximum temperature difference of 10 °C or less, for example, 5 °C or less, such as 0.5 °C to 3 °C. Yet further, additionally or alternatively, the maximum temperature difference can be 4% or less, for example, 2 % or less, such as 0.2 % to 1.1%.

[00106] With exemplary reference to Fig. 6A, the heat transfer elements 570 may protrude from the wall into the inner volume 560 of the evaporation crucible 521. For example, a first heat transfer element 571 and a second heat transfer element 572 may be provided, e.g. in a cup-like shape for accommodating liquid source material in the respective first and second heat transfer elements. Further, the first and the second heat transfer elements may be connected to at least a portion of any one or more of the side walls 561-566 of the evaporation crucible 521. More specifically, the first heat transfer element 571 can be arranged above the second heat transfer element 572, i.e. the first heat transfer element 571 is arranged closer to the crucible opening 504 than the second heat transfer element 572.

[00107] According to embodiments which can be combined with any other embodiment described herein, the first and the second heat transfer elements may have the same shape or may differ with respect to geometry and/or size. In particular, the heat transfer elements 570 have a plate-like portion 570a and a tube-like portion 570b. The plate-like portion 570a may be

connected to the side wall 561-566 at least along a portion of the inner surface of the evaporation crucible 521. The tube-like portion 570b may be arranged at the center of the plate-like portion 570a. In particular, the tube-like portion 570b may extend towards the crucible opening 504 which provides a connection for a fluid exchange between the crucible and a distribution assembly, e.g. a distribution pipe. More specifically, the center of the opening of the tube-like portion 570b of the heat transfer elements 570 and the center of the crucible opening 504 may be arranged to align along a central axis 505 of the evaporation crucible 521.

[00108] According to some embodiments herein, the one or more heat transfer elements may be made of materials including metals or alloys with a high thermal conductivity. For example, the heat transfer elements may include any one or more elements chosen from the following list: titanium, stainless steel and diamond-like carbon (DLC). In embodiments herein, the material of the one or more heat transfer elements may be inert with respect to the source materials such that the heat transfer elements do not react with the source material during the evaporation process. Depending on the evaporation temperature of the source material used, the materials of the one or more heat transfer elements should be stable and inert at least up to the evaporation temperature of the source material, which may, for example, be anywhere between 150°C and 650°C or more.

[00109] With exemplary reference to FIG. 6B, according to alternative embodiments of the crucible, the evaporation crucible 521 may include one or more heat transfer elements 570, which protrude from the wall, particularly from the sidewalls, into the inner volume 560 of the crucible. In particular, the one or more heat transfer elements 570 may be provided in the form of plates 573, e.g. six plates as shown in FIG. 6B, which can be arranged within the inner volume of the crucible to guide the evaporated source materials towards the distribution assembly. More specifically, each of the six plates may protrude from the wall towards the center of the inner volume 560 of the evaporation crucible 521. For example, each of the six plates may be arranged to be perpendicular with respective side walls of the evaporation crucible 521, as exemplarily shown in FIG. 6D. In particular, any one or all of the plates 573 may extend into or through the wall of the crucible. For instance, as exemplarily shown in FIG. 6D, any one or more of the six plates may extend through each of the respective side walls and/or through the bottom wall 557 and/or through the top wall 558 of the evaporation crucible 521.

[00110] According to some embodiments of the crucible, the wall of the crucible may include a plurality of slits to accommodate the plates 573. The slits may extend completely

through the wall of the crucible. Accordingly, the slits may simplify the assembly procedure and ensure that heat is effectively conducted from the outside to the inner volume of the crucible. For instance, during assembly of the crucible the plates may be inserted into the slits and also welded from the outside to the crucible. Further, any one or more of the six plates may extend in a longitudinal direction, parallel to the central axis 505 of the evaporation crucible 521 anywhere from about 0% to about 100% of the total length 569 of the inner volume 560 of the evaporation crucible 521. For example, any one or more of the six plates may extend at least about 90% of the total length of the inner volume of the crucible.

[00111] With exemplary reference to FIG. 6C, according to alternative embodiments of the crucible, the one or more heat transfer elements 570 may include a plurality of plates 573, for example eighteen plates that are arranged within the inner volume 560 of the evaporation crucible 521. Similar to the embodiment shown in Fig. 5B, each of the eighteen plates may extend through the wall of the crucible. By increasing the number of plates, the surface area of the one or more heat transfer elements within the inner volume of the crucible may be increased. Further, having a plurality of heat transfer elements may allow the crucible to be modular in the sense that heat transfer elements can be added and/or taken out from the inner volume of the crucible depending on the particular beneficial implementations regarding heat distribution and space within the inner volume of the crucible. According to embodiments which can be combined with any other embodiment described herein, the plates may be arranged within the crucible such that the smallest absolute angle at the point of intersection between two adjacent planes, each plane extending parallel with one of the plates, is anywhere between about 5° and about 175°, such as for instance about 30°, about 45° or about 60°.

[00112] FIG. 6D shows a cross-sectional perspective view of the evaporation crucible 521 shown in Fig. 6B along line A-A. Fig. 6D shows the six heat transfer elements, e.g. plates 573, each protruding at an angle of about 90° with respect to a respective side wall. As is shown in Fig. 6D, each of the six plates may extend to an outer edge of the crucible. In particular, as exemplarily shown in Fig. 6D, at least four plates out of the six plates may protrude the same distance into the inner volume of the crucible. Alternatively, all of the six plates or more plates may protrude the same distance or each a different distance into the inner volume of the crucible.

[00113] Further, with exemplary reference to FIG. 6D, according to embodiments which can be combined with any other embodiment described herein, the evaporation crucible 521 may have a hexagonal geometry. Alternatively, the evaporation crucible 521 may include other

geometrical shapes such as a rectangular, circular, oval or triangular shape. Alternatively, the evaporation crucible 521 may have circular geometry, as exemplarily shown in FIG. 6E. In particular, according to the embodiment shown in FIG. 6E, the heat transfer elements may be provided in the form of eight plates which are arranged within the inner volume 560 of the crucible such that the smallest absolute angle at the point of intersection between two adjacent planes, each plane extending parallel with one of the plates, is about 45°. A symmetrical arrangement of the plurality of heat transfer elements, as shown in FIG. 6E, may be beneficial to ensure a homogenous distribution of heat within the inner volume of the crucible.

[00114] As exemplarily shown in FIG. 6E, the one or more heat transfer elements may be arranged within the inner volume of the crucible such that the center of the inner volume includes a free space, e.g. free cylindrical space, with a diameter D from at least $D=10$ mm to $D=35$ mm.

[00115] According to embodiments described herein, an evaporation source may include one or more evaporation crucibles and one or more distribution assemblies, particularly one or more distribution pipes. Typically, a respective one of the one or more distribution pipes can be in fluid communication with the respective one of the one or more evaporation crucibles. Such a configuration may in particular be beneficial for OLED devices in which one or more materials are evaporated simultaneously. Accordingly, as for example shown in FIG. 7A, three distribution pipes and corresponding evaporation crucibles can be provided next to each other. Accordingly, the evaporation source may also be referred to as an evaporation source array, e.g. wherein more than one kind of material is evaporated at the same time. Further, an evaporation source array having three distribution pipes and corresponding evaporation crucibles which are configured for evaporating organic material may also be referred to as a triple organic source.

[00116] With exemplary reference to FIGS. 7A to 7C, embodiments of a distribution assembly 530 as employed in the processing system as described herein are described. FIG. 7A shows a top view of a cross-section of a distribution assembly. The distribution assembly may include at least one distribution pipe, for example three distribution pipes, as exemplarily shown in FIG. 7A. The distribution pipe 533 can be an elongated pipe with an inner tube 537 and an outer tube 536. As exemplarily shown in FIG. 7A, typically three distribution pipes may be provided which have a non-circular cross-section perpendicular to the length of the distribution pipe. In particular, the cross-section perpendicular to the length of the distribution pipe can be triangular with rounded corners and/or cut-off corners as a triangle.

[00117] Accordingly, by providing a distribution assembly having two or more distribution pipes, an evaporation source for co-evaporation and co-deposition of different materials can be provided. Particularly, outlets of neighboring distribution pipes can be provided at a smaller distance. The smaller distance improves mixing of evaporated materials emitted through neighboring outlets.

[00118] Further, as exemplarily shown in FIG. 7A, the distribution pipes can be configured and arranged such that the evaporation direction of the one or more outlets of each distribution pipe is inclined to a symmetrical plane provided along the length of the distribution pipe. For example, the angle at which the main evaporation direction of the distribution pipe emits relative to the surface orthogonal of the substrate surface can be 20° or below, for example between 3° and 10° .

[00119] According to some embodiments, which can be combined with other embodiments described herein, the product of the length of the distribution pipe and the area of all outlets in the distribution pipe divided by the hydraulic diameter of the distribution pipe, i.e. the value calculated by the formula $N \cdot A \cdot L / D$, can be 7000 mm^2 or below, for example 1000 mm^2 to 5000 mm^2 . In this formula, N is the number of outlets in the distribution pipe, A is the cross-section area of one outlet, L is the length of the distribution pipe, and D is the hydraulic diameter of the distribution pipe.

[00120] According to some embodiments, a distribution pipe 533 may be heated by heating elements which are provided inside the inner tubes. The heating elements can be electrical heaters which can be provided by heating wires, e.g. coated heating wires, which are clamped or otherwise fixed to the inner tubes. Further, a cooling shield 538 can be provided surrounding the distribution pipe. As exemplarily shown in FIG. 6A, according to some embodiments, a first cooling shield 538A can surround two or more distribution pipes.

[00121] As described above, the source material which is evaporated in an evaporation crucible is distributed in the at least one distribution pipe and can exit the distribution pipe through outlets 539. Typically, a plurality of outlets 539 are distributed along the length of the distribution pipe. For example, the outlets may be provided by nozzles. Typically, the nozzles extend through a heat shield or a stack of heat shields of the distribution assembly. Accordingly, condensation of evaporated material at the heat shields can be reduced because the nozzle guides the metallic material through the heat shields. Further, the nozzle which can be heated to a temperature which is similar to the temperature inside may be provided, which is

in contact with the heated walls of the distribution pipe.

[00122] As described above, each distribution pipe is in fluid communication with the evaporation crucible. Further, as exemplarily shown in FIG. 7A, typically the at least one distribution pipe has a cross-section perpendicular to the length of the distribution pipe, which is non-circular, and which includes an outlet side at which the one or more outlets are provided, wherein the width of the outlet side of the cross-section is 30% or less of the maximum dimension of the cross-section.

[00123] According to embodiments which can be combined with any other embodiment described herein, an evaporator control housing 541 may be provided adjacent to the distribution assembly 530, particularly the distribution pipes, and connected thereto via a thermal insulator 542, as exemplarily shown in FIG. 7A. In particular, the evaporator control housing can be configured to maintain atmospheric pressure therein and is configured to house at least one element selected from the group consisting of: a switch, a valve, a controller, a cooling unit, a cooling control unit, a heating control unit, a power supply, and a measurement device. Accordingly, a component for operating the evaporation source for the evaporation source array can be provided under atmospheric pressure close to the evaporation crucible and the distribution pipe and can be moved through the deposition apparatus together with the evaporation source.

[00124] With exemplary reference to FIG. 7A, in addition to the first cooling shield 538A, a second cooling shield 538B can be provided. The second cooling shield 538B may include sidewalls which are arranged such that a U-shaped cooling shield is provided in order to reduce the heat radiation towards the deposition area, i.e. a substrate and/or a mask. For example, the cooling shields can be provided as metal plates having conduits for cooling fluid, such as water, attached thereto or provided therein. Additionally, or alternatively, thermoelectric cooling means or other cooling means can be provided to cool the cooled shields. Typically, the outer shields, i.e. the outermost shields surrounding the inner hollow space of a distribution pipe, can be cooled.

[00125] Accordingly, as described above, each of the distribution pipes may include heating elements, e.g. heater plates, and cooling shields, e.g. water cooled plates to control the temperature inside and outside the distribution pipe. Typically, all three distribution pipes may be surrounded by shields, particularly cooling shields, as exemplarily shown in FIG. 7A.

[00126] By providing heating elements and cooling shields for the evaporation source array as described herein, early condensation of the evaporating material inside the evaporating tubes can be prevented while at the same time heat load exposure of the substrate to be coated can be minimized.

[00127] In FIG. 7A, for illustrative purposes, evaporated source material exiting the outlets of the distribution pipes are indicated by arrows. Due to the essentially triangular shape of the distribution pipes, the evaporation cones originating from the three distribution pipes are in close proximity to each other, such that mixing of the source material from the different distribution pipes can be improved. In particular, the shape of the cross-section of the distribution pipes allow to place the outlets or nozzles of neighboring distribution pipes close to each other. According to some embodiments, which can be combined with other embodiments described herein, a first outlet or nozzle of the first distribution pipe and a second outlet or nozzle of the second distribution pipe can have a distance of 25 mm or below, such as from 5 mm to 25 mm. More specifically, the distance of the first outlet or nozzle to a second outlet or nozzle can be 10 mm or below.

[00128] According to yet further embodiments, which can be combined with other embodiments described herein, tube extensions of the nozzles can be provided. In light of the small distance between the distribution pipes, such tube extensions can be sufficiently small to avoid clogging or condensation therein. Tube extensions can be designed such that nozzles of two or even three sources can be provided in one line above each other, i.e. in one line along the extension of the distribution pipe, which can be a vertical extension. With this special design, it is even possible to arrange the nozzles of the two or three sources in one line over small tube extensions, so that a perfect mixing is achieved.

[00129] As further shown in FIG. 7A, a shielding device, particularly a shaper shielding device 517, can be provided, for example, attached to the second cooling shield 538B or as a part of the second cooling shield. By providing shaper shields, the direction of the vapor exiting the distribution pipe or pipes through the outlets can be controlled, i.e. the angle of the vapor emission can be reduced. According to some embodiments, at least a portion of the metallic material evaporated through the outlets or nozzles is blocked by the shaper shield. Accordingly, the width of the emission angle can be controlled. According to some embodiments, the shaper shielding device can also be cooled to further reduce the heat load emitted towards the deposition area. The shaper shields delimit the distribution cone of the metallic materials distributed towards the substrates, i.e. the shaper shields are configured to block at least a

portion of the evaporated source material.

[00130] Accordingly, embodiments of the distribution assembly including heat shields and/or cooling shields are configured to reduce a temperature rise of the substrates on which temperature-sensitive organic materials may be deposited. In particular, the temperature rise may be reduced to below 5 Kelvin, or even to below 1 K. Additionally, a stack of metal plates, for example up to 10 metal plates, can be provided to reduce the heat transfer from the evaporation source to the substrate. Further, a triangular shape of the evaporation source may be beneficial with respect to a reduction of the heated area which radiates heat towards the substrate. According to some embodiments, which can be combined with other embodiments described herein, the heat shields or metal plates can be provided with orifices for the outlet or nozzles and may be attached to at least the front side of the source, i.e. the side facing the substrate.

[00131] According to embodiments which can be combined with any other embodiment described herein, the outer outlets, particularly the outer nozzles, may include short tubes extending towards the nozzle tubes of the center distribution pipe tube extensions such that the outlets of the nozzles are closer together. In particular, the tube extensions can have a bend such as a 60° to 120° bend, e.g. a 90° bend. According to yet further embodiments, which can be combined with other embodiments described herein, a further shield 543 can be provided between the distribution pipes. For example, the further shield 543 can be a cooled shield or a cooled lug. Accordingly by such further shields, the temperature of the distribution pipes can be controlled independent from each other. For example, in the event that different materials are evaporated through neighboring distribution pipes, these materials may need to be evaporated at different temperatures. Accordingly, the further shield 543, e.g. a cooled shield, can reduce cross-talk between the distribution pipes in an evaporation source or an evaporation source array.

[00132] According to some embodiments, which can be combined with other embodiments described herein, the outlets (e.g. nozzles) can be arranged to have a main evaporation direction to be horizontal $\pm 20^\circ$. According to some specific embodiments, the evaporation direction can be oriented slightly upward, e.g. to be in a range from horizontal to 15° upward, such as 3° to 7° upward.

[00133] FIG. 7B shows a schematic sectional view of a distribution assembly 530 of an evaporation source according to embodiments described herein. The distribution assembly 530

includes three distribution pipes 533 each having a plurality of nozzles 544 which may be arranged along the length direction of the distribution pipes. The length direction of the distribution pipes in FIG. 7B is perpendicular to the drawing plane of FIG. 7B. The sectional plane of FIG. 7B intersects through the outlets of the respective nozzles in the three illustrated distribution pipes. As is indicated in FIG. 7B, evaporated source material may stream from the interior of the distribution pipe 533 through the outlet of the nozzles 544 toward the substrate 101. The nozzles 544 are configured for directing a plume 318 of evaporated source material toward the substrate 101.

[00134] With exemplary reference to FIG. 7B, according to embodiments, the distribution assembly 530 may further include a shaper shielding device 517, which may be arranged downstream from the plurality of nozzles 544. The shielding device may be configured for guiding the evaporated source material toward the substrate 101 and for individually shaping the plumes of evaporated source material. The shielding device may be detachably fixed to the distribution pipes, e.g. via fixing elements such as screws. The shielding device may include a plurality of apertures 545 wherein at least one aperture of the plurality of apertures 545 can be configured to individually shape the plume of evaporated source material emitted from a single associated nozzle. Alternatively, each aperture of the plurality of apertures of the shielding device may be configured to individually shape a single plume of evaporated source material that is emitted from a single associated nozzle. In other words, a separate aperture may be arranged in front of every nozzle of the plurality of nozzles.

[00135] Accordingly, each plume of evaporated source material emitted from the plurality of nozzles may be individually shaped by an associated aperture of the plurality of apertures. Individual shaping of the plumes of evaporated source material may lead to increased deposition accuracy and may reduce the shadowing effect provided by a mask. In particular, individually shaping the plumes of evaporated source material may lead to smaller plume opening angles with more clearly defined plume flanks. Large impact angles of the plumes on the mask and/or on the substrate can be avoided.

[00136] In some embodiments, the at least one aperture may have a diameter of 3 mm or more and 25 mm or less, particularly 5 mm or more and 15 mm or less. Therein, the diameter of the aperture may be measured at the front end 549 of the aperture which defines the maximum emission angle of the plume 318 propagating toward the substrate 101.

[00137] In some embodiments, the aperture may be arranged in front of the associated

nozzle, as exemplarily shown in FIG. 7B. For example, the main emission direction X of a nozzle may correspond to a connection line between the center of the outlet of the nozzle and the center of the aperture. The aperture 545 may be configured as a passage 546 for the plume 318 that is surrounded by a circumferential wall, wherein the circumferential wall 547 may be configured to block at least a portion of the plume 318 of evaporated source material emitted from the nozzle. In some embodiments, the circumferential wall 547 may be configured to block an outer angular portion of the plume 318 of evaporated source material. In some embodiments, the circumferential wall 547 may extend parallel to the main emission direction X from a base wall 548 of the shielding device, wherein the base wall 548 may extend essentially perpendicular to the main emission direction X. The base wall may have an opening for the plume or for an outlet of a nozzle to enter the aperture.

[00138] An “aperture” as used herein may refer to an opening or a passage at least partially surrounded by a wall which is configured to shape a single plume of evaporated source material which is guided therethrough, particularly for limiting the maximum opening angle of the plume and for blocking outer angular portions of the plume. In some embodiments, the passage may be entirely surrounded by a circumferential wall such as to shape the plume in every sectional plane which includes the main emission direction X of the associated nozzle.

[00139] In some embodiments, which may be combined with other embodiments herein, the shielding device may be arranged at a close distance to the distribution pipe, e.g. at a distance of 5 cm or less or 1 cm or less in the main emission direction X. Arranging the apertures at a close distance downstream from the nozzles may be beneficial because an individual shaping of the plumes may be possible even if adjacent nozzles of the plurality of nozzles are arranged at a close distance with respect to each other.

[00140] In some embodiments, the nozzles may at least partially protrude into the shielding device. In other words, there may be a sectional plane perpendicular to the main emission direction X which intersects both the nozzle and the shielding device. For example, as exemplarily shown in FIG. 7B, the outlet of the nozzle may protrude into the aperture. In particular, the nozzle outlet may protrude into the opening in the base wall 548 or into the passage 546 which is surrounded by the circumferential wall 547. This allows for shaping the plume 318 emitted from the nozzle directly downstream from the nozzle outlet such that adjacent nozzles can be positioned close to each other.

[00141] With exemplary reference to FIG. 7B, according to some embodiments which may

be combined with other embodiments described herein, the nozzles may not be in direct mechanical contact with the shielding device. In particular, the nozzles may protrude into the apertures at a distance from the aperture walls. For example, the minimum distance between the nozzle and the shielding device may be less than 3 mm or less than 1 mm and/or more than 0.1 mm. By avoiding direct contact between the nozzles and the shielding device, a thermal decoupling between the nozzles and the shielding device can be provided. Accordingly, a direct thermal conduction between the typically hot nozzles and the shielding device can be avoided such that a thermal radiation toward the substrate from the shielding device can be reduced.

[00142] In some embodiments, which may be combined with other embodiments described herein, the circumferential wall 547 may be configured to block the evaporated source material of the plume 318 of evaporated source material having an emission angle greater than a first maximum emission angle α (alpha) with respect to the main emission direction X in a first sectional plane. The drawing plane of FIG. 7B illustrates the first sectional plane. The first sectional plane may include the main emission direction X. In some embodiments, the first sectional plane is a horizontal plane and/or a plane that extends perpendicularly to the length direction of the distribution assembly, particularly the distribution pipe. As is depicted in FIG. 7B, the circumferential wall 547 of the aperture 545 is configured to block an outer angular portion of the plume 318 of evaporated source material in the first sectional plane such that the opening angle of the emission cone is limited to an angle of 2θ . In other words, the circumferential wall 547 blocks the portion of the evaporated source material emitted by the nozzle at an emission angle greater than the first maximum emission angle α (alpha). For example, the first maximum emission angle α (alpha) can be an angle from 10° to 45° , particularly from 20° to 30° , more particularly about 25° . Accordingly, the opening angle 2α of the emission cone in the first sectional plane may be 20° or more and 90° or less, particularly about 50° . As is indicated in FIG. 7B, the shadowing effect due to the mask can be reduced by reducing the first maximum emission angle α (alpha).

[00143] In some embodiments, which may be combined with other embodiments described herein, the circumferential wall 547 may be configured to block the evaporated source material of the plume 318 of evaporated source material having an emission angle greater than a second maximum emission angle with respect to the main emission direction X in a second sectional plane perpendicular to the first sectional plane. The second sectional plane may be a plane perpendicular to the drawing plane of FIG. 7B. The second sectional plane may include the main emission direction X. In some embodiments, the second sectional plane is a vertical plane

and/or a plane that extends parallel to the length direction of the distribution pipe. For instance, the circumferential wall 547 of the aperture may be configured to block an outer angular portion of the plume 318 of evaporated source material in the second sectional plane such that the opening angle of the emission cone is limited to an angle of 2β . In other words, the circumferential wall 547 may block the portion of the evaporated source material emitted by the nozzle at an emission angle greater than the second maximum emission angle β (beta) in the second sectional plane. For example, the second maximum emission angle β (beta) can be an angle from 10° to 60° , particularly from 30° to 40° , more particularly about 45° . Accordingly, the opening angle of the emission cone in the second sectional plane may be 20° or more and 120° or less, particularly about 90° . The shadowing effect due to the mask 330 in a plane perpendicular to the drawing plane of FIG. 3 can be reduced by reducing the second maximum emission angle β .

[00144] In some embodiments, the second maximum emission angle is an angle different from the first maximum emission angle, particularly an angle larger than the first maximum emission angle. This is because a larger maximum emission angle may be possible in the length direction of the distribution pipe. In particular, in the length direction of the distribution pipe, adjacent nozzles are typically configured to emit the same evaporation material, and the spacing of adjacent nozzles along the distribution pipe can be adjusted more easily. On the other hand, nozzles which are adjacent to each other in a direction perpendicular to the length direction of the distribution pipe may be configured to emit different materials such that accurately setting the overlap of the plumes of adjacent nozzles may be beneficial.

[00145] More specifically, the first sectional plane may be a horizontal plane, the first maximum emission angle α (alpha) may be from 20° to 30° , the second sectional plane may be a vertical plane, and the second maximum emission angle β (beta) may be from 40° to 50° . In some embodiments, a distance between two adjacent nozzles in the length direction of the distribution pipe may be from 1 cm to 5 cm, particularly from 2 cm to 4 cm. Accordingly, the distance between two adjacent apertures of the plurality of apertures, i.e. the distance between the respective aperture centers, may be from 1 cm to 5 cm, particularly from 2 cm to 4 cm. For example, the distance between two adjacent apertures may correspond to the distance between the two adjacent associated nozzles, respectively.

[00146] In some embodiments, which may be combined with other embodiments described herein, the aperture 545 is configured as a round passage for the plume 318 surrounded by a circumferential wall 547. A "round passage" may be understood as a passage with a rounded

contour, e.g. a curved contour, a circular contour, or an oval contour, in a sectional plane perpendicular to the main emission direction X. For example, the circumferential wall 547 may have a circular or an oval shape in a sectional plane perpendicular to the main emission direction X. A circular passage may shape the plume 318 such as to be rotationally symmetric with respect the main emission direction. An oval passage may shape the plume 318 such as to have a large opening angle in a first sectional plane corresponding to the major axis of the oval passage and to have a small opening angle in a second sectional plane corresponding to the minor axis of the oval passage. The major axis of the oval passage may be arranged in the vertical direction, and the minor axis of the oval passage may be arranged in the horizontal direction.

[00147] For example, according to some embodiments, the circumferential wall 547 may form a circle in a sectional plane perpendicular to the main emission direction X. The diameter of the circle, i.e. the inner diameter of the passage, may be 3 mm or more and 25 mm or less, particularly 5 mm or more and 15 mm or less. The diameter of the passage may be measured at a downstream end of the passage which defines the maximum opening angle of the plume 318. In some embodiments, the length of the circumferential wall 547 in the main emission direction X may be constant. In other embodiments, which may be combined with other embodiments described herein, the aperture 545 may be configured as a passage 546 for the plume 318 surrounded by a circumferential wall 547, wherein a length of the circumferential wall in a main emission direction X varies in a circumferential direction. More particularly, the front end 549 of the circumferential wall 547 which is directed toward the substrate may have a distance from the nozzle outlet that varies in the circumferential direction. By providing a varying length of the circumferential wall in the circumferential direction, the opening angle of the plume 318 may be configured to be different in various sectional planes.

[00148] More specifically, as exemplarily illustrated in FIG. 7B, the circumferential wall 547 may have a first length T1 in a first sectional plane which includes the main emission direction X, and the circumferential wall may have a second length T2 smaller than the first length T1 in a second sectional plane which includes the main emission direction X and extends perpendicular to the first sectional plane. The first sectional plane may be perpendicular to the length direction of the distribution pipe, e.g. a horizontal plane. The second sectional plane may be parallel to the length direction of the distribution pipe, e.g. a vertical plane.

[00149] The length of the circumferential wall may vary continuously from the first length

T1 in the first sectional plane to the second length T2 in the second sectional plane. In other words, the front end 549 of the circumferential wall 547 may include no step and no discontinuity in the circumferential direction. Accordingly, the opening angle of the plume 318 may vary gradually in the circumferential direction which may be beneficial for improving the deposition accuracy. In particular, in some embodiments, the first length T1 may be a length between 8 mm and 20 mm, particularly about 12 mm, and/or the second length T2 may be a length between 3 mm and 15 mm, particularly about 6.5 mm. The “length” of the circumferential wall may correspond to the length of a projection of a vector connecting the nozzle outlet and the front end of the circumferential wall in a respective sectional plane on the main emission direction X.

[00150] Further, it should be noted that pixels with sharp edges may be deposited on the substrate, when the front end 549 of the circumferential wall has a wave-like or undulating shape in a circumferential direction. Accordingly, wave crests may be positioned in the first sectional plane, i.e. the drawing plane of FIG. 7B, and wave bases may be arranged in the second sectional plane, i.e. a plane perpendicular to the first sectional plane. The front end 549 of the circumferential wall 547 may include two wave crests and two wave bases.

[00151] In some embodiments, which may be combined with other embodiments described herein, the shaper shielding device may include a plurality of separate shielding units arranged next to each other. Each shielding unit of the plurality of separate shielding units may include one or more apertures of the plurality of apertures 545. “Separate” shielding units as used herein may refer to two or more shielding units which are not in direct contact with each other and which are provided as separate components without a direct mechanical connection. As is indicated in FIG. 7B, the shielding units of the plurality of separate shielding units are not in direct contact with each other. For example, the separate shielding units may be separately fixed to a respective distribution pipe with one or more respective fixing elements. In some embodiments, each shielding unit of the plurality of separate shielding units may include a single aperture of the plurality of apertures 545. Each aperture may be configured as a passage surrounded by a shielding wall configured for shaping a single plume of evaporated source material.

[00152] According to some embodiments which can be combined with other embodiments described herein, at least one shaper shielding unit of the plurality of separate shielding units includes two, three, four, five or more apertures of the plurality of apertures 545, which may be connected to each other by a support structure, for example in a linear arrangement. A distance

between two adjacent apertures of the at least one shielding unit may be 1 cm or more and 5 cm or less, respectively. In some embodiments, each shielding unit of the plurality of shielding units may include two or more apertures of the plurality of apertures. Mounting of the shaper shielding device to the distribution pipes can be facilitated when the number of shielding units of the shielding device is reduced. Accordingly, increasing the number of apertures per shielding unit may be beneficial.

[00153] In some embodiments, the number of apertures per shielding unit is 10 or less, particularly 5 or less. The shielding units may follow a local thermal expansion and contraction of one of the distribution pipes more easily, when the shielding units do not extend over a substantial length. In particular, adjacent shielding units may move relative to one another when one of the distribution pipes expands or contracts. It is indicated in FIG. 7B that the shielding unit connected to the distribution pipe 533 is mechanically decoupled from the remaining shielding units such as to be movable relative to the remaining shielding units. For example, the temperature of the first distribution pipe 533A may vary differently from the temperature of the second distribution pipe 533B and from the temperature of the third distribution pipe 533C such that the distribution pipes may slightly move relative to each other during deposition. The shielding units may follow the movement of the respective distribution pipe, because the shielding units are mechanically decoupled from the remaining shielding units, respectively. Accordingly, the plumes of evaporated source material may be shaped in a stable way even when the distribution pipes move relative to each other or when one of the distribution pipes thermally expands or contracts. The one or more apertures of a shielding unit may follow the movement of the one or more associated nozzles, respectively. Accordingly, in some embodiments, each shielding unit of the plurality of separate shielding units may be mechanically decoupled from the remaining shielding units of the plurality of separate shielding units such as to not follow a thermally caused movement of the remaining shielding units.

[00154] In some embodiments, which may be combined with other embodiments described herein, at least one shielding unit of the plurality of separate shielding units may be connected to a single distribution pipe such as to follow a thermal expansion and contraction of the single distribution pipe in a length direction of the single distribution pipe, particularly such as to move with respect to a further shielding unit connected to the single distribution pipe when the single distribution pipe thermally contracts or expands.

[00155] With exemplary reference to FIG. 7B, according to some embodiments the main

emission direction of the nozzles of the first distribution pipe 533A may be inclined with respect to the main emission direction of the nozzles of the second distribution pipe 533B and/or of the third distribution pipe 533C. For example, the main emission directions may be inclined such that the plumes of evaporated source material emitted from the first distribution pipe 533A may overlap with the plumes of evaporated source material emitted from the second distribution pipe 533B and/or from the third distribution pipe 533C. In some embodiments, the distribution pipes are arranged such that main emission directions of the distribution pipes may intersect essentially on the surface of the substrate. The plumes emitted from different distribution pipes in a sectional plane may be directed to essentially the same area on the substrate.

[00156] FIG. 7C shows a distribution assembly 530 according to embodiments described herein in a sectional view, wherein the sectional plane extends in the length direction of the distribution pipe 533. The length direction of the distribution pipe may be a vertical direction. In some embodiments, a second distribution pipe 533B and/or a third distribution pipe 533C may run essentially parallel to the first distribution pipe 533A in a vertical direction, as shown in FIG. 7B. As exemplarily shown in FIG. 7C, typically the distribution pipe 533 includes a plurality of nozzles 544 which are arranged next to each other in the length direction of the distribution pipe. A first nozzle 544A and a second nozzle 544B of the plurality of nozzles are shown in FIG. 7C. A first plume 318A of evaporated source material is emitted by the first nozzle 544A, and a second plume 318B of evaporated source material is emitted by the second nozzle 544B.

[00157] Typically, a shaper shielding device 517 is arranged downstream from the plurality of nozzles to shape the plumes of evaporated source material emitted from the plurality of nozzles. The shaper shielding device may include a plurality of individual shielding units, wherein a first shielding unit 518A of the plurality of shielding units 518 is depicted in FIG. 7C. The first shielding unit 518A may include a first aperture 545A and a second aperture 545B which may be configured according to the aperture 545 as described with reference to FIG. 7B. The first aperture 545A can be configured to individually shape the first plume 318A emitted from the first nozzle 544A, and the second aperture 545B can be configured to individually shape the second plume 318B emitted from the second nozzle 544B.

[00158] According to typical embodiments, a shielding unit may include more than two apertures of the plurality of apertures, e.g. three, four, or five apertures, in a linear arrangement. The apertures may be connected by a support structure, e.g. a plate element. The apertures of

the shielding unit may be configured for individually shaping the plumes of evaporated source material of three, four or five adjacent nozzles which are provided next to each other along the length direction of the distribution pipe. The distribution pipe may include 10 or more nozzles provided in a linear arrangement. Accordingly, more than one shielding unit, e.g. two, three or more shielding units may be fixed to the distribution pipe in a linear arrangement. Each shielding unit of the plurality of separate shielding units may be mechanically fixed to a single distribution pipe of the two or more distribution pipes of the evaporation source. The shielding units may be mechanically and/or thermally decoupled from one another such that a relative movement between the individual shielding units may be possible. Accordingly, the shielding units may move relative to one another when the distribution pipe on the shielding units are fixed to extend or contract.

[00159] For example a shielding unit, such as the first shielding unit 518A shown in FIG. 7C, may be fixed to the distribution pipe 533 such as to be thermally decoupled from the distribution pipe 533. For example, the first shielding unit 518A may be held at a distance from the distribution pipe 533 by one or more spacer elements 519 which may be arranged between the shielding unit and the distribution pipe. The spacer elements 519 may be configured as support sections arranged between the nozzles of the distribution pipe. The spacer elements 519 may provide a small contact area, in order to reduce a heat flow from the distribution pipe 533 toward the shielding unit 518. For example, the contact area of a spacer element 519 may be 1 mm² or less, particularly 0.25 mm² or less. The shielding unit 518 may be fixed to the distribution pipe via one or more fixing elements, e.g. screws, which may be made of a material with low heat conductivity.

[00160] The length of the shielding unit 518 in the length direction of the distribution pipe may be 20 cm or less, particularly 10 cm or less. Due to the small length of the shielding units, the shielding units may follow a thermally caused local movement, e.g. an expansion or contraction movement, of the distribution pipe. For example, a first shielding unit fixed to the distribution pipe may move away from a second shielding unit fixed to the same distribution pipe, when the distribution pipe expands. The first shielding unit fixed to the distribution pipe may move toward the second shielding unit fixed to the same distribution pipe, when the distribution pipe contracts.

[00161] In some embodiments, which may be combined with other embodiments described herein, the shielding unit is rigidly fastened to the distribution pipe at a single fixing portion along the length direction of the shielding unit, e.g. at a center portion of the shielding unit. At

further positions, the shielding unit may be fixed to the distribution pipe 533 such as to allow a relative movement between the shielding unit and the distribution pipe. For example, in the embodiment shown in FIG. 7C, the first end portion 518C of the shielding unit, e.g. the first shielding unit 518A, and the second end portion 518D of the shielding unit may be movably fixed to the distribution pipe, e.g. via a fixing element such as a screw penetrating through a slotted hole that may be provided in the shielding device. In some embodiments, the slotted hole may provide a clearance between the distribution pipe and the shielding unit in the length direction of the shielding unit of more than 0.01 mm and less than 0.5 mm, for example about 0.1 mm.

[00162] FIG. 7D shows a shielding unit 518 of a shaper shielding device for an evaporation source according to embodiments described herein in a perspective view. As described above, a shaper shielding device may include a plurality of separate shielding units, for example three or more, particularly 12 or more shielding units. Typically, the shielding unit 518 may include two or more apertures 545 and/or ten or less apertures, particularly five apertures. Each aperture may be configured as a passage surrounded by a shielding wall, e.g. a circumferential wall 547. Round passages, particularly circular passages may be space-saving and easy to manufacture. Round passages may have the further advantage that the evaporated source material may impact on the shielding wall at the same impact angles in the circumferential direction due to the rotational symmetry. Evaporated source material may uniformly accumulate on the shielding wall in the circumferential direction during deposition. Cleaning of the shielding unit may become easier.

[00163] As exemplarily shown in FIG. 7D, the apertures of the shielding unit 518 may be arranged in a linear arrangement with a distance of 1 cm or more and 5 cm or less, particularly about 2 cm, between adjacent apertures. The shielding unit 518 may be configured as a one-piece component, wherein the apertures may be connected by a shield support structure 518B, e.g. an elongated plate element. The shielding unit 518 may have a width of 3 cm or less, 2 cm or less, or even 1 cm or less. The shield support structure 518B may include one or more holes at a first end and one or more holes at a second end opposite the first end for fixing the shielding unit to a distribution pipe, e.g. via screws or bolts. In some embodiments, further holes may be provided between the apertures, respectively. Each aperture of the shielding unit 518 may be configured to individually shape a plume of evaporated source material emitted from a single associated nozzle of the evaporation source. In some embodiments described herein, the apertures of the shielding unit 518 may have a diameter between 3 mm and 25 mm,

particularly between 5 mm and 15 mm, respectively. A small diameter of the apertures of the shielding unit may improve the deposition accuracy. However, a small aperture diameter tends to clog more easily, which may cause a deterioration of the deposition efficiency and deposition uniformity. Accordingly, the distribution assembly as described herein provides for maintaining high deposition accuracy over a long time period, while at the same time preventing clogging of the apertures.

[00164] With exemplary reference to FIGS. 7E and 7F, exemplary embodiments of a nozzle for a distribution assembly as described herein are described. Typically, the nozzle 590 may include a directing portion 591, which guides the evaporated material to the substrate to be coated. The directing portion may, for instance, be formed and designed so as to cause a desired shape and intensity of the vapor plume released from the nozzle. Further, the nozzle 590 typically includes a connecting portion 592 for exchangeable connection of the nozzle to a distribution assembly, such as a distribution pipe 533, as described herein. In particular, the connecting portion 592 of the nozzle 590 may be configured for screwing the nozzle to a distribution pipe. For instance, the connecting portion of the nozzle may include a thread area 593, particularly an external thread, as exemplarily shown in FIG. 7E. Accordingly, the distribution pipe according to some embodiments described herein may include an internal thread for connecting the nozzle to the distribution pipe. According to some embodiments, the thread of the nozzle may have an outer diameter of typically between about 5 mm and about 15 mm, more typically between 6 mm and 12 mm, and even more typically between 8 mm and 10 mm.

[00165] As exemplarily shown in FIG. 7F, typically the nozzle 590 includes a nozzle inlet 594, a nozzle outlet 595, and a passageway 596 between the nozzle inlet and the nozzle outlet. Accordingly, the evaporated material coming from the crucible is guided in the distribution pipe and enters the nozzle 590 through the nozzle inlet 594. The evaporated material then passes through the passageway 596 of the nozzle and exits the nozzle at the nozzle outlet 595. According to some embodiments, the shape of the passageway 596 may be any suitable shape for guiding evaporated material through the nozzle. For instance, the cross-section of the nozzle passageway may have a substantially circular shape, but may also have an elliptical shape, or the shape of an elongated hole. In some embodiments, the cross-section of the nozzle passage may have a substantially rectangular, a substantially quadratic, or even a substantially triangular shape.

[00166] Further, according to some embodiments which can be combined with any other

embodiment described herein, the passageway 596 of the nozzle may include a first section 596A and a second section 596B. The first section 596A of the nozzle provides a first section size 598A, e.g. a first diameter, and a first section length 597A. The second section 596B of the nozzle provides a second section size 598B, e.g. a second diameter, and a second section length 597B. According to embodiments described herein, the second section size may typically be between 2 to 10 times larger than the first section size, more typically between 2 and 8 times larger, and even more typically between 3 and 7 times larger. In one example, the second section size may be 4 times larger than the first section size.

[00167] In some embodiments, which may be combined with other embodiments described herein, the first section 596A of the passageway 596 of the nozzle may include the nozzle inlet 594, and the second section 596B of the passageway 596 of the nozzle may include the nozzle outlet 595. According to some embodiments, the first section size 598A may typically be between 1.5 mm and about 8 mm, e.g. between about 2 mm and about 4 mm. The second section size 598B may be between 3 mm and about 20 mm, e.g. between about 4 mm and about 10 mm. According to some embodiments, which may be combined with other embodiments described herein, the length of the first section 596A of the passageway and or the length of the second section 596B of the passageway may be between 2 mm and about 20 mm, more typically between about 2 mm and about 15 mm, and even more typically between about 2 mm and about 10 mm.

[00168] According to some embodiments, the first section may be configured to increase the uniformity of the evaporated material guided from the distribution pipe into the nozzle, especially by having a smaller size than the second section. According to some embodiments, the comparatively narrow first section may force the particles of the evaporated material to arrange in a more uniform manner. Making the evaporated material more uniform in the first section may for instance include making the density of the evaporated material, the velocity of the single particles and/or the pressure of the evaporated material more uniform.

[00169] According to embodiments described herein, the second section (being typically arranged adjacent to the first section) may be configured for increasing the directionality of the evaporated material. For instance, the evaporated material flowing from the first section to the second section will spread when leaving the first section which has a smaller size than the second section. The second section, however, may catch the evaporated material spreading from the first section and direct the evaporated material towards the substrate. When comparing the plume of evaporated material from a material deposition arrangement according to

embodiments described herein to a plume of evaporated material of known systems, the plume is more precisely directed towards the substrate, or towards a mask (e.g. a pixel mask).

[00170] According to some embodiments, which can be combined with any other embodiment described herein, a transitional section may be provided between the first section 596A and the second section 596B. For example, in contrast to a step transition as shown in FIG. 7F, the transitional section may be configured to provide a slope between the first section 596A and the second section 596B. Typically, the length of the transitional section may be between $1/6$ and $4/6$, more particularly between $1/6$ and $1/2$ and even more particularly between $1/3$ and $1/2$ of the first and/or second section length.

[00171] According to some embodiments, which may be combined with other embodiments described herein, the nozzles referred to herein may be designed to form a plume having a $\cos^n$ like shaped profile, wherein n is in particular larger than 4. In one example, the nozzle is designed to form a plume having a $\cos^6$ like shaped profile. The nozzle achieving a $\cos^6$ formed plume of evaporated material may be useful if a narrow shape of the plume is desired. For instance, a deposition process including masks for the substrate having small openings (such as openings having a size of about $50\text{ }\mu\text{m}$ and below, for instance $20\text{ }\mu\text{m}$) may benefit from the narrow $\cos^6$ shaped plume and the material exploitation may be increased since the plume of evaporated material does not spread on the mask but passes the openings of the mask. According to some embodiments, the nozzle may be designed so that the relation of the length of the nozzle and the size of the passageway of the nozzle stand in a defined relation, such as having a ratio of 2:1 or larger. According to additional or alternative embodiments, the passageway of the nozzle may include steps, inclinations, collimator structure(s) and/or pressure stages for achieving the desired plume shape.

[00172] According to some embodiments, the nozzle is configured to provide a mass flow of less than 1 sccm, more typically only a fractional amount of 1 sccm, and even more typically below 0.5 sccm. In one example, the mass flow in a nozzle according to embodiments described herein may be less than 0.1 sccm, such as 0.05 or 0.03 sccm. In some embodiments, the pressure in the distribution pipe, and at least partially in the nozzle may typically be between about 10-2 mbar and 10-5 mbar, and more typically between about 10-2 mbar and 10-3 mbar.

[00173] With exemplary reference to FIG. 7F, according to some embodiments which can be combined with any other embodiment described herein, the nozzle may include a first

nozzle material 599A and a second nozzle material 599B. For instance, the first nozzle material 599A may be selected to have a thermal conductivity value of larger than 21 W/mK. The second nozzle material 599B may be selected to be inert to evaporated organic material. For example, the second nozzle material 599B can be a part of the nozzle. Alternatively, the second nozzle material 599B may be used to provide a coating on the inner surface of the passageway.

[00174] According to some embodiments, the thickness of the second nozzle material may typically be in a range of some nanometers to several micrometers. In one example, the thickness of the second nozzle material in the nozzle opening may typically be between about 10 nm to about 50 μm , more typically between about 100 nm to about 50 μm , and even more typically between about 500 nm to about 50 μm . In one example, the thickness of the second nozzle material may be about 10 μm .

[00175] Typically, the first nozzle material may be selected to have a thermal conductivity larger than the thermal conductivity of the distribution pipe, to which the nozzle may be connected. In some embodiments, the first nozzle material may be selected to be inert to evaporated organic materials. Typically, the first nozzle material may include at least one material of the group consisting of Cu, Ty, Ta, Nb, Ti, DLC or graphite. In one example, the nozzle includes copper and provides a coating of a material on the inner side of the nozzle passageway, e.g. Ta, Nb, Ti, DLC, stainless steel, quartz glass and graphite.

[00176] Accordingly, in view of the above, it is to be understood that by providing a distribution assembly with nozzles according to embodiments described herein, a plume of evaporated material can be more precisely directed towards the substrate or towards a mask such that the deposition accuracy can be improved.

[00177] With exemplary reference to FIGS. 8A to 8E, embodiments of a service module 610 for the processing system are described. As described with reference to FIGS. 1A and 1B, typically a service module may be connected to a process module of the processing system as described herein. In particular, a vacuum maintenance chamber of the service module can be connected to the vacuum process chamber of the process module via an opening configured for the transfer of a deposition source, particularly an evaporation source, from the vacuum process chamber to the vacuum maintenance chamber. In particular, the opening may include a gate valve which is configured for opening and closing a vacuum seal between the vacuum process chamber and the vacuum maintenance chamber. Accordingly, a deposition source can be transferred to the service module while the gate valve is in an open state. Thereafter, the gate

valve can be closed to provide a vacuum seal between the vacuum process chamber and the vacuum maintenance chamber. If the valve is closed, the vacuum maintenance chamber can be vented and opened for maintenance of the deposition source without breaking the vacuum in the vacuum process chamber. Alternatively, as described with reference to FIGS. 8C to 8E, a sealing device configured for sealing off the opening between the vacuum process chamber and the vacuum maintenance chamber may be provided.

[00178] FIG. 8A shows a perspective view of a service module 610 which can be employed in a processing system 100 as described herein. In particular, as exemplarily shown in FIG. 8A, the service module is configured for housing a deposition source 520 as described herein. More specifically, the service module can be configured for housing two deposition sources which may be used interchangeably in the process module. For example, a first deposition source may be used for a deposition process in the process module, while a second deposition source is under maintenance in the service module.

[00179] For instance, in the exemplary embodiment as shown in FIG. 8A, the deposition source 520 is mounted on a source support (e.g. a source cart) on top of which a source shield (e.g. the material collection unit 40 as described in more detail with reference to FIGS 7A to 7E) is installed in order to protect a service flange 615 of the service module 610 from any overspray of evaporated material provided by the deposition source. Particularly, the service flange 615 may be configured and arranged such that a deposition source in the service module is surrounded by the service flange 615. More specifically, typically the service module includes two service flanges for two deposition sources which can be present in the service module. For instance, a first source service flange can be electromagnetically attached to the process module while at the same time, a second source service flange is in the service position inside the service module. In particular, the service flange can be configured to provide a sealing between the vacuum process chamber and the vacuum maintenance chamber.

[00180] Typically, the source service flange is an aluminum casting which can include an atmospheric box. The atmospheric box may include all major connections for the media arm, such as power cables, communication cables, and cooling water supply lines. The media arm is also referred to as connection device 630 herein and is described in more detail with reference to FIG. 8B.

[00181] With exemplary reference to FIG. 8A, according to embodiments which can be combined with any other embodiments described herein, the service module 610 may include a

service module door 614 for providing access to the maintenance area in order to maintain a deposition source. In particular, the service module door 614 may include a sliding mechanism 613 for opening the service module door 614. For example, when the service module is under atmospheric conditions, the service module door 614 may be opened. In particular, the service module door may be opened by opening and closing clamps and using a handrail to manually open the door. As exemplarily shown in FIG. 8A, the service module door may be moved on rails, particularly on linear rails, of the sliding mechanism 613. Accordingly, by providing a service module having a vacuum maintenance chamber which can be vented independently from the vacuum process chamber, it is possible to maintain or exchange a deposition source in the vacuum maintenance chamber without venting the vacuum process chamber such that the production process, e.g. of display devices, can be continued.

[00182] Further, as exemplarily shown in FIG. 8A, typically the service module includes a media supply 640 for the deposition source. In particular, the media supply 640 includes a supply passage which can be configured and arranged such that a supply to the deposition source can be provided from the top of the service module, as exemplarily shown in FIG. 8A. More specifically, the supply passage can be configured for supplying the deposition source, e.g., with electrical connections and/or media such as fluids (e.g., water) and/or gases. The supply passage may be configured for guiding one or more lines and/or cables therethrough, such as water supply lines, gas supply lines and/or electric cables. In some implementations, the supply passage may be configured for providing an atmospheric environment, i.e. the supply passage can be configured to maintain atmospheric pressure therein even when a surrounding such as the vacuum process chamber and/or the vacuum maintenance chamber is evacuated to a technical vacuum.

[00183] As exemplarily shown in FIG. 8B, according to some embodiments which can be combined with other embodiments described herein, the service module 610 may be provided with a transportation apparatus 720 for contactless transportation of a deposition source assembly, as described in more detail with reference to FIGS. 10A-10C. Typically, the transportation apparatus for contactless transportation of a deposition source assembly includes a guiding structure 770 configured for guiding the source support 531. Typically, the source support 531 is configured to be transferable from the vacuum process chamber to the vacuum maintenance chamber (and vice versa) together with the deposition source, which is indicated by the deposition source assembly 730 depicted in dashed lines in FIG. 8B.

[00184] With exemplary reference to FIG. 8B, according to some embodiments, a sealing

device 620 may be provided which can be configured for closing and opening the connection between the vacuum process chamber and the vacuum maintenance chamber. In some implementations, the sealing device 620 can be attached to the deposition source assembly. For example, the sealing device 620 can be a plate that is configured for sealing off an opening between the vacuum process chamber and the vacuum maintenance chamber substantially vacuum-tight. Accordingly, when the opening between the vacuum process chamber and the vacuum maintenance chamber is closed or sealed by the sealing device, the vacuum maintenance chamber can be vented and opened for maintenance of the deposition source without breaking the vacuum in the vacuum process chamber.

[00185] As exemplarily indicated by the double-sided arrow in FIG. 8B, typically the source support 531, onto which the deposition source (not shown in FIG. 8B) can be mounted, is moveable with respect to the sealing device 620. In particular, as exemplarily shown in FIG. 8B, a connection device 630 connecting the source support 531 and the sealing device 620 may be provided. The connection device may also be referred to as media supply arm herein. In particular, the media supply arm is a telescope arm and is configured to move simultaneously forwards and backwards with the deposition source inside the process module. As an example, the connection device 630 can be configured for guiding the translational movement of the source support 531 with respect to the sealing device 620. Additionally or alternatively, the connection device 630 can provide or accommodate a media supply for the deposition source. As an example, the connection device 630 can be an arm, in particular a passive arm. In some embodiments, at least a portion of the connection device 630 provides an atmospheric environment to prevent any particle impact on the media supply. As an example, the atmospheric environment can be provided inside the connection device 630, and can in particular be provided inside the arm.

[00186] In some implementations, the arm can include two or more arm portions connected by respective hinges to allow the relative movement between the source support 531 and the sealing device 620. As an example, the connection device 630 may include a first arm 632 and a second arm 634, as exemplarily shown in FIG. 8B. Typically, the first arm and/or the second arm are configured as supply tubes for housing supply lines. The first arm 632 has a first end portion 632A connected to the source support 531 and a second end portion 632B connected to a third end portion 634C of the second arm 634 via a hinge 636, which can be arranged inside a housing. According to some embodiments, an atmospheric box, e.g. for housing supply equipment, may be provided at the connection between the first end portion 632A of the first

arm 632 and the source support 531. The second arm 634 has a fourth end portion 634D connected to the vacuum process chamber and/or the vacuum maintenance chamber 616. According to typical embodiments, the connection device 630 is provided inside the service flange 615.

[00187] Further, typically for load balancing purposes during extension and contraction of the media supply arm, a spring system may be installed at the media supply arm. In particular, the spring system may be arranged and configured such that during extension of the media supply arm, e.g. when the source support is moved away from the sealing device, one or more springs of the spring system are extended such that a balancing retraction force is generated which counteracts the weight of the telescope arm.

[00188] With exemplary reference to FIG. 8B, according to some embodiments which can be combined with other embodiments described herein, a rotatable device 625 may be provided within the vacuum maintenance chamber 616. In particular, the rotatable device 625 can be configured for receiving the source support onto which the deposition source may be mounted. Typically, the rotatable device 625 may also be configured to receive the service flange. As an example, the rotatable device 625 can be a rotatable platform. In some embodiments, a drive configured for driving or rotating the rotatable device 625 may be provided. For instance, the drive may be connected to the rotatable device 625 via a shaft, e.g., a hollow shaft.

[00189] According to some embodiments, the rotatable device 625 can be configured for supporting two or more deposition sources. As an example, a first deposition source, e.g., to be serviced or exchanged, can be transferred from the vacuum process chamber to the vacuum maintenance chamber, and in particular onto the rotatable device 625. A second deposition source, e.g., a serviced or new one, can also be provided on the rotatable device 625. When both deposition sources, i.e., the first deposition source and the second deposition source, are positioned on the rotatable device 625, the rotatable device 625 is rotated, e.g., about 180 degrees, so that the first deposition source and the second deposition source exchange positions. Then, the second deposition source can be transferred into the vacuum process chamber and the opening connecting the vacuum process chamber and the vacuum maintenance chamber can be sealed, e.g., by the sealing device 620 which may be connected to the second deposition source.

[00190] FIGS. 8C to 8E show schematic top views of a process module 510 attached to a service module 610 of a processing system according to embodiments described herein,

wherein a first deposition source 520A and a second deposition source 520B are illustrated in different states during operation of the processing system. In particular, FIG. 8C shows a first deposition source 520A which is positioned in the vacuum process chamber 540, and a second deposition source 520B which is positioned in the vacuum maintenance chamber 616, particularly on the rotatable device 625.

[00191] As shown in FIG. 8D, the first deposition source 520A, e.g., to be serviced or exchanged, can be transferred from the vacuum process chamber 540 to the vacuum maintenance chamber 616, and in particular onto the rotatable device 625. As an example, the first deposition source 520A and the second deposition source 520B can be positioned back-to-back on the rotatable device 625, e.g., with their sealing devices being oriented towards each other. In other words, both sealing devices can be positioned or sandwiched between the first deposition source and the second deposition source.

[00192] When both evaporation sources, i.e., the first deposition source 520A and the second deposition source 520B, are positioned on the rotatable device 625, the rotatable device 625 is rotated, e.g., about 180 degrees, so that the first deposition source 520A and the second deposition source 520B exchange positions. In FIG. 8D, the rotation is indicated with arrows. Then, the second deposition source 520B can be transferred into the vacuum process chamber 540 and the opening connecting the vacuum process chamber 540 and the vacuum maintenance chamber 616 can be sealed, e.g., by the sealing device 620 of the second deposition source 520B. The vacuum maintenance chamber 616 can be vented for servicing or removal of the first deposition source 520A. Accordingly, embodiments of the processing system as described herein allow for an exchange of deposition sources without having to break the vacuum in the vacuum process chamber. Such a configuration in which a first deposition source 520A can be exchanged by a second deposition source 520B, e.g. by employing a service module 610 as described herein, can be beneficial when two different layers or stack of two different layers shall be deposited on the substrate in one process module. In particular, for depositing two layers of different material on the substrate, a first layer can be deposited on the substrate by the first deposition source and subsequently a second layer can be deposited on the substrate by the second deposition source.

[00193] According to some embodiments, which can be combined with other embodiments described herein, the at least one deposition source, e.g. the first deposition source 520A and the second deposition source 520B, may include an actuator, for example a torque motor, an electric rotor or a pneumatic rotor. The actuator can provide a torque via a vacuum rotation

feed-through, for example a ferrofluid sealed rotation feed-through. In particular, the actuator can be configured to rotate at least the distribution assembly, particularly the distribution pipes, around an axis, which is essentially vertical. Typically, the source support 531 is configured to house the actuator and the feed-through.

[00194] With exemplary reference to FIGS. 9A and 9B, embodiments of a routing module 410 for the processing system 100 are described. In particular, a perspective view of a routing module 410 is shown in FIG. 9A and a top view of two adjacent routing modules each being connected to a process module 510 are shown in FIG. 9B.

[00195] As exemplarily shown in FIG. 9A, typically the routing module 410 includes a rotation unit 420 which is configured to rotate the substrate carrier and/or the mask carrier such that the substrate carrier and/or the mask carrier can be transferred to a neighboring connected process module. In particular, the rotation unit 420 may be provided in a vacuum routing chamber 417, particularly a vacuum routing chamber which can be configured to provide vacuum conditions as described herein. More specifically, the rotation unit may include a rotation drive configured for rotating a support structure 418 for supporting a substrate carrier and/or a mask carrier around a rotation axis 419, as exemplarily shown in FIG. 9A. In particular, the rotation drive may be configured for providing a rotation of at least 180° of the rotation unit in a clockwise and an anti-clockwise direction.

[00196] Further, as exemplarily shown in FIG. 9A, the routing module 410 typically includes at least one first connecting flange 431 and at least one second connecting flange 432. For example, the at least one first connecting flange 431 may be configured for connecting a process module as described herein. The at least one second connecting flange 432 may be configured for connecting a further routing module or a vacuum swing module, as exemplarily described with respect to FIGS. 1A and 1B. Typically, the routing module includes four connecting flanges, e.g. two first connecting flanges and two second connecting flanges, each pair of which being arranged on opposing sides of the routing module. Accordingly, the routing module may include three different types of connecting flanges, also referred to as routing flanges herein, e.g. a connecting flange for connecting a process module, a connecting flange for connecting a swing module, and a connecting flange for connecting a further routing module. Typically, some or all of the different types of connecting flanges have a casing frame-like structure which are configured for providing vacuum conditions inside the casing frame-like structure. Further, typically the connecting flanges may include an entrance/exit for the mask carrier and an entrance/exit for the substrate carrier.

[00197] In FIG. 9B a portion of a processing system is shown in which two process modules are connected to each other via two adjacent routing modules. In particular, FIG. 9B shows a portion of a processing system in which a first routing module 411 is connected to a first process module 511 and to a further routing module 412. The further routing module 412 is connected to a further process module 512. As shown in FIG. 9B, a gate valve 115 can be provided between neighboring routing modules. The gate valve 115 can be closed or opened to provide a vacuum seal between the routing modules. The existence of a gate valve may depend on the application of the processing system, e.g. on the kind, number, and/or sequence of layers of organic material deposited on a substrate. Accordingly, one or more gate valves can be provided between transfer chambers. Alternatively, no gate valve is provided between any of the transfer chambers.

[00198] As described with reference to FIG. 9A, according to some embodiments which can be combined with other embodiments described herein, one or more of the routing modules may include a vacuum routing chamber 417 provided with a rotation unit 420. Therein, the substrate provided in a substrate carrier and/or the mask provided in a mask carrier employed during operation of the processing system can be rotated around a rotation axis 419, e.g. a vertical central axis.

[00199] Typically, the rotation unit 420 is configured for a rotating transportation track arrangement 715 including the first transportation track 711 and the second transportation track 712, as exemplarily shown in FIG. 9B. Accordingly, the orientation of the transportation track arrangement 715 inside the routing module can be varied. In particular, the routing module may be configured such that the first transportation track 711 and the second transportation track 712 can be rotated by at least 90°, for example by 90°, 180° or 360°, such that the carriers on the tracks are rotated in the position to be transferred in one of the adjacent chambers of the processing system.

[00200] According to typical embodiments, the first transportation track 711 and the second transportation track 712 are configured for contactless transportation of the substrate carrier and the mask carrier. In particular, the first transportation track 711 and the second transportation track 712 may include a further guiding structure 870 and a drive structure 890 configured for a contactless translation of the substrate carrier and the mask carrier, as described in more detail with reference to FIGS. 11A-11E.

[00201] As illustrated in FIG. 9B, in the first routing module 411, two substrates, e.g. a first

substrate 101A and a second substrate 101B, are rotated. The two transportation tracks, e.g. the first transportation track 711 and the second transportation track 712, on which the substrates are located, are rotated with respect to the two transportation tracks, which extend from the transportation track arrangement 715 of the first process module 511. Accordingly, two substrates on the transportation tracks are provided in a position to be transferred to an adjacent further routing module 412.

[00202] As exemplarily shown in FIG. 9B, according to some embodiments, which can be combined with other embodiments described herein, the transportation tracks of transportation track arrangement 715 may extend from the vacuum process chamber 540 into a vacuum routing chamber 417. Accordingly, one or more of the substrates 101 can be transferred from a vacuum process chamber to an adjacent vacuum routing chamber. Further, as exemplarily shown in FIG. 9B, a gate valve 115 may be provided between a process module and a routing module which can be opened for transportation of the one or more substrates. As exemplarily shown in FIG. 9B, also the further process module 512 can be connected to the further routing module 412 by a gate valve 115. Accordingly, it is to be understood that a substrate can be transferred from the first process module to the first routing module, from the first routing module to the further routing module, and from the further routing module to a further process module. Accordingly, several processes, e.g. depositions of various layers of organic material on a substrate can be conducted without exposing the substrate to an undesired environment, such as an atmospheric environment or non-vacuum environment.

[00203] As described above, according to some embodiments, which can be combined with other embodiments described herein, the processing system may be configured such that a substrate can be moved out of a process module along a first direction. In that way, the substrate is moved along an essentially straight path into an adjacent vacuum chamber, for example, a vacuum routing chamber which may also be referred to as vacuum transfer chamber herein. In the transfer chamber, the substrate can be rotated such that the substrate can be moved along a second straight path in a second direction different from the first direction. As exemplarily shown in FIG. 9B, the second direction can be substantially perpendicular to the first direction. For transferring the substrate to the further process module 512, the substrate can be moved from the first routing module 411 into the further routing module 412 in the second direction and can then be rotated in the further routing module 412, e.g. by 180°. Thereafter, the substrate can be moved into the further process module 512.

[00204] With exemplary reference to FIGS. 10A-10C, a transportation apparatus 720 for

contactless transportation of a deposition source assembly is described. Typically, the transportation apparatus 720 is arranged in a vacuum process chamber 540 of process module 510 as described herein. In particular, the transportation apparatus 720 is configured for contactless levitation, transportation and/or alignment of the deposition source. The contactless levitation, transportation and/or alignment of the deposition source is beneficial in that no particles are generated during transportation, for example due to mechanical contact with guide rails. Accordingly, embodiments of the transportation apparatus 720 described herein provide for an improved purity and uniformity of the layers deposited on the substrate, since particle generation is minimized when using the contactless levitation, transportation and/or alignment.

[00205] The term “contactless” as used throughout the present disclosure can be understood in the sense that the weight of an element employed in the processing system, e.g. a deposition source assembly, a carrier or a substrate, is not held by a mechanical contact or mechanical forces, but is held by a magnetic force. Specifically, the deposition source assembly or the carrier assembly is held in a levitating or floating state using magnetic forces instead of mechanical forces. As an example, the transportation apparatuses described herein may have no mechanical means, such as a mechanical rail, supporting the weight of the deposition source assembly. In some implementations, there can be no mechanical contact between the deposition source assembly and the rest of the transportation apparatus at all during movement of the deposition source past the substrate.

[00206] A further advantage, as compared to mechanical means for guiding the deposition source, is that embodiments described herein do not suffer from friction affecting the linearity of the movement of the deposition source along the substrate to be coated. The contactless transportation of the deposition source allows for a frictionless movement of the deposition source, wherein a target distance between the deposition source and the substrate can be controlled and maintained with high precision and speed. Further, the levitation allows for fast acceleration or deceleration of the deposition source speed and/or fine adjustment of the deposition source speed. Accordingly, the processing system as described herein provides for an improved layer uniformity, which is sensitive to several factors, such as e.g. variations in the distance between the deposition source and the substrate, or variations in the speed at which the deposition source is moved along the substrate while emitting material.

[00207] Further, the material of mechanical rails typically suffers from deformations which may be caused by evacuation of a chamber, by temperature, usage, wear, or the like. Such deformations affect the distance between the deposition source and the substrate, and hence

affect the uniformity of the deposited layers. In contrast, embodiments of the transportation apparatus as described herein allow for a compensation of any potential deformations present, e.g. in the guiding structure. In particular, embodiments of the transportation apparatus described herein allow for a contactless translation of a deposition source assembly along one, two or three spatial directions for aligning the deposition source. The alignment of the deposition source may be an alignment, e.g. translational or rotational, with respect to a substrate to be coated, e.g. in order to position the deposition source at a target distance from the substrate. Typically, the alignment or the positioning relative to the substrate is conducted while the deposition source is moved past the substrate for depositing material on the substrate. More specifically, the apparatus can be configured for a contactless translation of the deposition source assembly along a vertical direction, e.g. the y-direction, and/or along one or more transversal directions, e.g. the x-direction and z-direction, as described in more detail with reference to FIGS. 10A to 10C. An alignment range for the deposition source may be 2 mm or below, more particularly 1 mm or below.

[00208] Further, embodiments of the transportation apparatus described herein allow for a contactless rotation of the deposition source assembly with respect to one, two or three rotation axes for angularly aligning the deposition source. The alignment of the deposition source may e.g. involve positioning the deposition source in a target vertical orientation with respect to the substrate. In particular, the transportation apparatus may be configured for contactless rotation of the deposition source assembly around a first rotation axis, a second rotation axis and/or a third rotation axis. The first rotation axis may extend in a transversal direction, e.g. the x-direction or source transportation direction. The second rotation axis may extend in a transversal direction, e.g. the z-direction. The third rotation axis may extend in a vertical direction, e.g. the y-direction. Rotation of the deposition source assembly with respect to any rotation axis may be provided within an angle of 2° or below, e.g. from 0.1 degrees to 2 degrees or from 0.5 degrees to 2 degrees.

[00209] In the present disclosure, the terminology of “substantially parallel” directions may include directions which make a small angle of up to 10 degrees with each other, or even up to 15 degrees. Further, the terminology of “substantially perpendicular” directions may include directions which make an angle of less than 90 degrees with each other, e.g. at least 80 degrees or at least 75 degrees. Similar considerations apply to the notions of substantially parallel or perpendicular axes, planes, areas or the like.

[00210] Some embodiments described herein involve the notion of a “vertical direction”. A

vertical direction is considered to be a direction substantially parallel to the direction along which the force of gravity extends. A vertical direction may deviate from exact verticality (the latter being defined by the gravitational force) by an angle of, e.g., up to 15 degrees. For example, the y-direction described herein (indicated with “Y” in the figures) is a vertical direction. In particular, the y-direction shown in the figures defines the direction of gravity.

[00211] In particular, the transportation apparatus described herein can be used for vertical substrate processing. Therein, the substrate is vertically oriented during processing of the substrate, i.e. the substrate is arranged parallel to a vertical direction as described herein, i.e. allowing possible deviations from exact verticality. A small deviation from exact verticality of the substrate orientation can be provided, for example, because a substrate support with such a deviation might result in a more stable substrate position or a reduced particle adherence on a substrate surface. An essentially vertical substrate may have a deviation of $\pm 15^\circ$ or below from the vertical orientation.

[00212] Embodiments described herein may further involve the notion of a “transversal direction”. A transversal direction is to be understood to distinguish over a vertical direction. A transversal direction may be perpendicular or substantially perpendicular to the exact vertical direction defined by gravity. For example, the x-direction and the z-direction described herein (indicated with “X” and “Z” in the FIGS. 10A to 10C) are transversal directions. In particular, the x-direction and the z-direction shown in the figures are perpendicular to the y-direction (and to each other). In further examples, transversal forces or opposing forces, as described herein, are considered to extend along transversal directions.

[00213] As exemplarily illustrated in FIG. 10A, the transportation apparatus 720 typically includes a deposition source assembly 730 including a deposition source 520 as described herein 520 and a source support 531 for supporting the deposition source 520. In particular, the source support 531 may be a source cart. The deposition source 520 may be mounted to the source support 531. As indicated by the arrows in FIG. 10A, the deposition source 520 is adapted for emitting material for depositing on the substrate 101. Further, as exemplarily shown in FIG. 10A, a mask 330 may be arranged between the substrate 101 and the deposition source 520. The mask 330 can be provided for preventing deposition of material emitted by the deposition source 520 on one or more regions of the substrate 101. For example, the mask 330 may be an edge exclusion shield configured for masking one or more edge regions of the substrate 101, such that no material is deposited on the one or more edge regions during the coating of the substrate 101. As another example, the mask may be a shadow mask for masking

a plurality of features, which are deposited on the substrate with the material from the deposition source assembly.

[00214] Further, with exemplary reference to FIG. 10A, the deposition source assembly 730 may include a first active magnetic unit 741 and a second active magnetic unit 742. The transportation apparatus 720 typically further includes a guiding structure 770 extending in a deposition source transportation direction. The guiding structure 770 may have a linear shape extending along the source transport direction. The length of the guiding structure 770 along the source transportation direction may be from 1 m to 6 m. The first active magnetic unit 741, the second active magnetic unit 742 and the guiding structure 770 are configured for providing a first magnetic levitation force F1 and a first magnetic levitation force F2 for levitating the deposition source assembly 730, as exemplarily indicated in FIG. 10A.

[00215] In the present disclosure, an “active magnetic unit” or “active magnetic element”, may be a magnetic unit or magnetic element adapted for generating an adjustable magnetic field. The adjustable magnetic field may be dynamically adjustable during operation of the transportation apparatus. For example, the magnetic field may be adjustable during the emission of material by the deposition source 520 for deposition of the material on the substrate 101 and/or may be adjustable in between deposition cycles of a layer formation process. Alternatively or additionally, the magnetic field may be adjustable based on a position of the deposition source assembly 730 with respect to the guiding structure. The adjustable magnetic field may be a static or a dynamic magnetic field. According to embodiments, which can be combined with other embodiments described herein, an active magnetic unit or element can be configured for generating a magnetic field for providing a magnetic levitation force extending along a vertical direction. Alternatively, an active magnetic unit or element may be configured for providing a magnetic force extending along a transversal direction, e.g. an opposing magnetic force as described below. For instance, an active magnetic unit or active magnetic element as described herein, may be or include an element selected from the group consisting of: an electromagnetic device; a solenoid; a coil; a superconducting magnet; or any combination thereof.

[00216] As exemplarily shown in FIG. 10A, during operation of the transportation apparatus 720, at least a portion of the guiding structure 770 may face the first active magnetic unit 741. The guiding structure 770 and/or the first active magnetic unit 741 may be arranged at least partially below the deposition source 520.

[00217] In operation, the deposition source assembly 730 is movable with respect to the guiding structure along the x-direction. Further, position adjustment may be provided along the y-direction, along the z-direction and/or along an arbitrary spatial direction. The guiding structure is configured for contactless guiding of the movement of the deposition source assembly. The guiding structure 770 may be a static guiding structure which can be statically arranged in the vacuum process chamber. In particular, the guiding structure 770 may have magnetic properties. For example, the guiding structure 770 may be made of a magnetic material, e.g. a ferromagnetic, particularly ferromagnetic steel. Accordingly, the guiding structure may be or include a passive magnetic unit.

[00218] The terminology of a “passive magnetic unit” or “passive magnetic element” is used herein to distinguish from the notion of an “active” magnetic unit or element. A passive magnetic unit or element may refer to a unit or an element with magnetic properties which are not subject to active control or adjustment. For instance, a passive magnetic unit or element may be adapted for generating a magnetic field, e.g. a static magnetic field. A passive magnetic unit or element may not be configured for generating an adjustable magnetic field. Typically, a passive magnetic unit or element may be a permanent magnet or have permanent magnetic properties.

[00219] As compared to a passive magnetic unit or element, an active magnetic unit or element offers more flexibility and precision in light of the adjustability and controllability of the magnetic field generated by the active magnetic unit or element. According to embodiments described herein, the magnetic field generated by an active magnetic unit or element may be controlled to provide for an alignment of the deposition source. For example, by controlling the adjustable magnetic field, a magnetic levitation force acting on the deposition source assembly may be controlled with high accuracy, thus allowing for a contactless vertical alignment of the deposition source by the active magnetic unit or element.

[00220] According to embodiments, which can be combined with other embodiments described herein, the transportation apparatus may include a drive system configured for driving the deposition source assembly 730 along the guiding structure 770. The drive system may be a magnetic drive system configured for transporting the deposition source assembly 730 without contact along the guiding structure 770 in the source transportation direction. The drive system may be a linear motor. The drive system may be configured for starting and/or stopping movement of the deposition source assembly along the guiding structure. According to some embodiments, which can be combined with other embodiments described herein, the

contactless drive system can be a combination of a passive magnetic unit, particularly a passive magnetic unit provided at the guiding structure, and an active magnetic unit, particularly an active magnetic unit provided in or at the deposition source assembly.

[00221] According to embodiments, the speed of the deposition source assembly along the source transportation direction may be controlled for controlling the deposition rate. The speed of the deposition source assembly can be adjusted in real-time under the control of the controller. The adjustment can be provided for compensating a deposition rate change. A speed profile may be defined. The speed profile may determine the speed of the deposition source assembly at different positions. The speed profile may be provided to or stored in the controller. The controller may control the drive system such that the speed of the deposition source assembly is in accordance with the speed profile. Accordingly, a real-time control and adjustment of the deposition rate can be provided, so that the layer uniformity can be further improved. A translational movement of the deposition source assembly along the source transportation direction, as considered according to embodiments described herein, allows for a high coating precision, in particular a high masking precision during the coating process, since the substrate and the mask can remain stationary during coating.

[00222] During the contactless movement of the deposition source assembly 730 along the guiding structure 770, the deposition source 520 may emit, e.g. continuously emit, material towards the substrate in the substrate receiving area for coating the substrate. The deposition source assembly 730 may sweep along the substrate such that, during one coating sweep, the substrate can be coated over the entire extent of the substrate along the source transportation direction. In a coating sweep, the deposition source assembly 730 may start from an initial position and move to a final position without changing direction. According to embodiments, which can be combined with other embodiments described herein, the length of the guiding structure 770 along the deposition source transportation direction may be 90% or more, 100% or more, or even 110% or more of the extent of a substrate receiving area along the source transportation direction. Typically, the substrate receiving area has dimensions, e.g. a length and a width, which are the same or slightly (e.g. 5-20 %) larger than the corresponding dimensions of the substrate. Accordingly, a uniform deposition at the edges of the substrate can be provided. Further, a translational movement of the deposition source assembly along the source transportation direction allows for a high coating precision, in particular a high masking precision during the coating process, since the substrate and the mask can remain stationary during coating.

[00223] According to embodiments, which can be combined with other embodiments described herein, the deposition source may be aligned without contact, e.g. vertically, angularly or transversally aligned as described herein, while the deposition source moves along the substrate for depositing material on the substrate. The deposition source may be aligned while the deposition source is transported along the guiding structure. The alignment may be a continuous or an intermittent alignment during the movement of the deposition source. The alignment during the movement of the deposition source may be performed under the control of the controller. The controller may receive information about a current position of the deposition source along the guiding structure. The alignment of the deposition source may be performed under the control of the controller based on information regarding the current position of the deposition source. Accordingly, potential deformations of the guiding structure can be compensated. Accordingly, the deposition source can be maintained at a target distance or a target orientation with respect to the substrate at all times throughout the movement of the deposition source along the substrate, thus further improving the uniformity of the layers deposited on the substrate. Alternatively or additionally, aligning the deposition source may be performed when the deposition source is static. For example, alignment may be performed for a temporarily static deposition source in between deposition cycles.

[00224] With exemplary reference FIG. 10A, the transportation apparatus 720 may include a deposition source assembly 730 with a first plane 733 including a first rotation axis 734 of the deposition source assembly 730. The deposition source assembly 730 may include the first active magnetic unit 741 arranged at a first side 733A of the first plane 733 and the second active magnetic unit 742 arranged at a second side 733B of the first plane 733. The first active magnetic unit 741 and the second active magnetic unit 742 are configured for magnetically levitating the deposition source assembly 730. In particular, the first active magnetic unit 741 and the second active magnetic unit 742 are each adapted for generating a magnetic field, e.g. an adjustable magnetic field, for providing respective magnetic levitation forces acting on the deposition source assembly 730. Accordingly, the first active magnetic unit 741 and the second active magnetic unit 742 are configured for rotating the deposition source 520 around the first rotation axis 734 for alignment of the deposition source 520.

[00225] As exemplarily shown in FIG. 10A, the first plane 733 may extend through the deposition source assembly 730, particularly through a body portion of the deposition source assembly 730. The first plane 733 may include the first rotation axis 734 of the deposition source assembly 730. According to typical embodiments, the first rotation axis 734 may extend

through a center of mass of the deposition source assembly 730. In operation, the first plane 733 may extend in a vertical direction. The first plane 733 may be substantially parallel or substantially perpendicular to a substrate receiving area or substrate. In operation, the first rotation axis 734 may extend along a transversal direction.

[00226] The magnetic field generated by the first active magnetic unit 741 interacts with the magnetic properties of the guiding structure 770 to provide for a first magnetic levitation force F1 acting on the deposition source assembly 730. The first magnetic levitation force F1 acts on a portion of the deposition source assembly 730 on the first side 733A of the first plane 733. In FIG. 10A, the first magnetic levitation force F1 is represented by a vector provided on the left-hand side of the first plane 733. According to embodiments, which can be combined with other embodiments described herein, the first magnetic levitation force F1 may at least partially counteract the weight G of the deposition source assembly 730.

[00227] The notion that a magnetic levitation force “partially” counteracts the weight G, as described herein, entails that the magnetic levitation force provides a levitation action, i.e. an upward force, on the deposition source assembly, but that the magnetic levitation force alone may not suffice to levitate the deposition source assembly. The magnitude of a magnetic levitation force which partially counteracts the weight is smaller than the magnitude of the weight G.

[00228] The magnetic field generated by the second active magnetic unit 742 shown in FIG. 9E interacts with the magnetic properties of the guiding structure 770 to provide for a second magnetic levitation force F2 acting on the deposition source assembly 730. The second magnetic levitation force F2 acts on a portion of the deposition source assembly 730 on the second side 733B of the first plane 733. In FIG. 10A, the second magnetic levitation force F2 is represented by a vector provided on the right-hand side of the first plane 733. The second magnetic levitation force F2 may at least partially counteract the weight G of the deposition source assembly.

[00229] A superposition of the first magnetic levitation force F1 and the second magnetic levitation force F2 provides for a superposed magnetic levitation force acting on the deposition source assembly 730. The superposed magnetic levitation force may fully counteract the weight G of the deposition source assembly. The superposed magnetic levitation force may suffice to provide for a contactless levitation of the deposition source assembly 730, as illustrated in FIG. 10A. Yet, further contactless forces may be provided such that the first magnetic

levitation force F1 and the second magnetic levitation force F2 provides for a superposed magnetic levitation force which may partially counteract the weight G and the first magnetic levitation force F1, the second magnetic levitation force F2, and the further contactless forces provides for a superposed magnetic levitation force to fully counteract the weight G.

[00230] According to embodiments, which can be combined with other embodiments described herein, the first active magnetic unit may be configured for generating a first adjustable magnetic field for providing a first magnetic levitation force F1. The second active magnetic unit may be configured for generating a second adjustable magnetic field for providing a second magnetic levitation force F2. The apparatus may include a controller 755 configured for individually controlling the first active magnetic unit 741 and/or the second active magnetic unit 742 for controlling the first adjustable magnetic field and/or the second adjustable magnetic field for aligning the deposition source. More specifically, the controller 755 may be configured for controlling the first active magnetic unit and the second active magnetic unit for translationally aligning the deposition source in a vertical direction. By controlling the first active magnetic unit and the second active magnetic unit, the deposition source assembly may be positioned into a target vertical position. Further, the deposition source assembly may be maintained in the target vertical position under the control of the controller.

[00231] An individual control of the first active magnetic unit and/or of the second active magnetic unit may offer an additional benefit with regard to the alignment of the deposition source. An individual control allows for a rotation of the deposition source assembly 730 around the first rotation axis 734 for angularly aligning the deposition source 520. For example, with reference to FIG. 10A, individually controlling the first active magnetic unit 741 and/or the second active magnetic unit 742 in a manner such that the first magnetic levitation force F1 is greater than the second magnetic levitation force F2 results in a torque which may provide for a clockwise rotation of the deposition source assembly 730 around the first rotation axis 734. Similarly, a second magnetic levitation force F2, which is greater than the first magnetic levitation force F1 may result in a counter-clockwise rotation of the deposition source assembly 730 around the first rotation axis 734.

[00232] The rotational degree of freedom provided by the individual controllability of the first active magnetic unit 741 and of the second active magnetic unit 742 allows controlling an angular orientation of the deposition source assembly 730 with respect to the first rotation axis 734. Under the control of the controller 755, a target angular orientation may be provided and/or maintained. The target angular orientation of the deposition source assembly may be a

vertical orientation, for example an orientation according to which the first plane 733 is parallel to the y-direction, as illustrated in FIG. 10A. Alternatively, a target orientation may be a tilted or slightly tilted orientation according to which the first plane 733 is inclined at a target angle with respect to the y-direction.

[00233] With exemplary reference to FIG. 10A, according to embodiments which can be combined with any other embodiment described herein, the transportation apparatus 720 may include a first passive magnetic unit 745, e.g. a permanent magnet, and a further active magnetic unit 743. The first passive magnetic unit 745 may be arranged at the second side 733B of the first plane 733. In operation, the first passive magnetic unit 745 may face a second portion 772 of the guiding structure 770 and/or may be provided between the first plane 733 and the second portion 772.

[00234] The further active magnetic unit 743 may be arranged at the first side 733A of the first plane 733. In operation, the further active magnetic unit 743 may face a first portion 771 of the guiding structure 770 and/or may be provided at least partially between the first plane 733 and the first portion 771. Typically, the further active magnetic unit 743 may be of a same type as the first active magnetic unit 741, as the second active magnetic unit 742. For example, the further active magnetic unit 743, the first active magnetic unit 741 and/or the second active magnetic unit 742 may be electromagnets of a same type. As compared to the first active magnetic unit 741 and the second active magnetic unit 742, the further active magnetic unit 743 may have a different spatial orientation. In particular, with respect to e.g. the first active magnetic unit 741, the further active magnetic unit 743 may be rotated, e.g. by about 90 degrees, around a transversal axis perpendicular to the drawing plane of FIG. 10A.

[00235] The further active magnetic unit 743 may be configured for generating a magnetic field, in particular an adjustable magnetic field. The magnetic field generated by the further active magnetic unit 743 interacts with the magnetic properties of the guiding structure 770 to provide for a first opposing transversal force O1 acting on the deposition source assembly 730. The first opposing transversal force O1 is a magnetic force. Accordingly, the further active magnetic unit 743 and the guiding structure 770 are configured for providing a first opposing transversal force O1. The first opposing transversal force is an adjustable force counteracting a first transversal force. Further, with exemplary reference to FIG. 10A the controller 755 may be configured for controlling the further active magnetic unit 743 to provide for a transversal alignment.

[00236] Typically, the first passive magnetic unit 745 and the guiding structure 770 are configured for providing a first transversal force T1.

[00237] In particular, the first passive magnetic unit 745 may be configured for generating a magnetic field. The magnetic field generated by the first passive magnetic unit 745 may interact with the magnetic properties of the guiding structure 770 to provide for the first transversal force T1 acting on the deposition source assembly 730. The first transversal force T1 is a magnetic force. The first transversal force T1 extends along a transversal direction, as described herein. The first transversal force T1 may extend along a direction substantially perpendicular to the source transportation direction. For example, the first transversal force T1 may be substantially parallel to the z-direction, as shown in Fig. 10A.

[00238] With exemplary reference to FIG. 10A, it is to be understood that the first opposing transversal force O1 extends along a transversal direction. The transversal direction may be the same as, or substantially parallel to, the transversal direction along which the first transversal force T1 extends. For example, the forces T1 and O1 shown in FIG. 10A both extend along the z-direction. In particular, the first opposing transversal force O1 and the first transversal force T1 are opposing or counteracting forces. This is illustrated in FIG. 10A by the aspect according to which the forces T1 and O1 are represented by vectors of equal lengths pointing in opposite directions along the z-direction. The first opposing transversal force O1 and the first transversal force T1 may have equal magnitudes. The first opposing transversal force O1 and the first transversal force T1 may extend in opposite directions along a transversal direction. The first transversal force T1 and the first opposing transversal force O1 may be substantially perpendicular to a substrate receiving area or substrate or source transportation direction.

[00239] For example, as illustrated in FIG. 10A, the first transversal force T1 may result from a magnetic attraction between the first passive magnetic unit 745 and the guiding structure 770. The magnetic attraction urges the first passive magnetic unit 745 towards the guiding structure 770, in particular towards the second portion 772 of the guiding structure 770. The first opposing transversal force O1 may result from a magnetic attraction between the further active magnetic unit 743 and the guiding structure 770. The magnetic attraction urges the further active magnetic unit 743 towards the guiding structure 770, in particular towards the first portion 771 of the guiding structure 770.

[00240] Alternatively, the first transversal force T1 may result from a magnetic repulsion between the first passive magnetic unit 745 and the guiding structure 770. The first opposing

transversal force O1 may result from a magnetic repulsion between the further active magnetic unit 743 and the guiding structure 770. Also in this case, the forces T1 and O1 are counteracting forces. Accordingly, the first opposing transversal force O1 may fully counteract the first transversal force T1. The first opposing force O1 may counteract the first transversal force T1 such that the net force acting on the deposition source assembly 730 along a transversal direction, e.g. the z-direction, is zero. Accordingly, the deposition source assembly 730 may be held without contact at a target position along a transversal direction.

[00241] As illustrated in FIG. 10A, the controller 755 may be configured for controlling the further active magnetic unit 743. The control of the further active magnetic unit 743 may include a control of an adjustable magnetic field generated by the further active magnetic unit 743 for controlling the first opposing transversal force O1. Controlling the further active magnetic unit 743 may allow for a contactless alignment of the deposition source 520 along a transversal direction, e.g. the z-direction. In particular, by suitably controlling the further active magnetic unit 743, the deposition source assembly 730 may be positioned into a target position along a transversal direction. The deposition source assembly may be maintained in the target position under the control of the controller.

[00242] The first transversal force T1, being provided by a passive magnetic unit, is a static force which is not subject to adjustment or control during operation of the transportation apparatus. Accordingly, the first transversal force T1 may be considered as a force which simulates a hypothetical “gravitational-type” force acting along a transversal direction. For example, the first transversal force T1 can be considered to simulate a hypothetical weight, along a transversal direction, of an object. In turn, within this paradigm, the first opposing transversal force O1 may be considered to simulate a hypothetical “levitation-type” force counteracting the hypothetical weight of the object along the transversal direction. Accordingly, the contactless transversal alignment of the deposition source, as provided by a control of the further active magnetic unit for counteracting the first transversal force T1, can be understood from the same principles as the contactless vertical alignment of the deposition source, as provided by a control of the first active magnetic unit for counteracting the actual, i.e. vertical, weight G of the deposition source assembly. Accordingly, the control of the further active magnetic unit for transversally aligning the deposition source may be performed using the same technology and based on the same control algorithms as are used for the control of the first active magnetic unit for providing vertical alignment. This provides for a simplified approach for aligning the deposition source.

[00243] According to embodiments, which can be combined with other embodiments described herein, the first portion 771 and the second portion 772 of the guiding structure 770 may be separate parts of the guiding structure 770. In operation, the first portion 771 of the guiding structure 770 may be arranged at the first side 733A of the first plane 733. The second portion 772 of the guiding structure 770 may be arranged at the second side 733B of the first plane 733.

[00244] According to embodiments, which can be combined with other embodiments described herein, one or more, or all, of the magnetic units included in the deposition source assembly 730 may be mounted to the source support 531. For example, as shown in FIGS. 10A and 10B, the first active magnetic unit 741, the second active magnetic unit 742, the first passive magnetic unit 745 and/or the further active magnetic unit 743, as described herein, may be mounted to the source support 531.

[00245] The first portion 771 and the second portion 772 of the guiding structure 770 may each be passive magnetic units and/or may include one or more passive magnet assemblies. For example, the first portion 771 and the second portion 772 may each be made of a ferromagnetic material, e.g. ferromagnetic steel. The first portion 771 may include a first recess 773 and a second recess 774. In operation, a magnetic unit of the deposition source assembly 730, e.g. the first active magnetic unit 741 as shown in Fig. 10B, may be at least partially arranged in the first recess 773. In operation, another magnetic unit of the deposition source assembly, e.g. the further active magnetic unit 743, may be at least partially arranged in the second recess 774. The first portion 771 of the guiding structure 770 may have an E-shaped profile in a cross-section perpendicular to the source transport direction, e.g. the x-direction. An E-shaped profile substantially along the length of the first portion 771 may define the first recess 773 and the second recess 774. Similarly, the second portion 772 may include a third recess 775 and a fourth recess 776. In operation, a magnetic unit of the deposition source assembly 730, e.g. the second active magnetic unit 742 as shown in FIG. 9B, may be at least partially arranged in the third recess 775, and the first passive magnetic unit 745 may be at least partially provided in the fourth recess 776. The first passive magnetic unit 745 may interact with a further passive magnetic unit 746 provided at the guiding structure 770. The second portion 772 may have an E-shaped profile in a cross-section perpendicular to the source transportation direction. An E-shaped profile substantially along the length of the second portion 772 may define the third recess 775 and the fourth recess 776.

[00246] By arranging the magnetic units of the deposition source assembly 730 at least

partially in the respective recesses of the guiding structure 770, an improved magnetic interaction between the guiding structure and the magnetic units in the respective recess is obtained for providing the forces F1, F2, T1 and/or O1 as described herein.

[00247] With exemplary reference to FIG. 10B, according to some embodiments of transportation apparatus, a passive magnetic drive unit 780 may be provided at the guiding structure. For example, the passive magnetic drive unit 780 can be a plurality of permanent magnets, particularly a plurality of permanent magnets forming a passive magnet assembly with varying pole orientation. The plurality of magnets can have alternating pole orientation to form the passive magnet assembly. An active magnetic drive unit 781 can be provided at or in the source assembly, e.g. the source support 531. The passive magnetic drive unit 780 and the active magnetic drive unit 781 can provide the drive, e.g. a contactless drive, for movement along the guiding structure, while the source assembly is levitated.

[00248] FIG. 10C shows a source support 531, e.g. a source cart, according to embodiments which can be combined with other embodiments described herein. As shown, the following units may be mounted to the source support 531: the deposition source 520; a first active magnetic unit 741; a second active magnetic unit 742; a third active magnetic unit 747; a fourth active magnetic unit 748; a fifth active magnetic unit 749; a sixth active magnetic unit 750; a first passive magnetic unit 751; a second passive magnetic unit 752; or any combination thereof. The fifth active magnetic unit 749 may be a further active magnetic unit 743 as described with reference to FIG. 10A.

[00249] Fig. 10C shows the first plane 733, as described herein, extending through the source support 531. The first plane 733 includes the first rotation axis 734, as described herein. As shown in FIG. 9C, in operation, the first rotation axis 734 may be substantially parallel to the x-direction.

[00250] In operation, the first rotation axis may extend along a transversal direction, e.g. substantially parallel to the x-direction. The first active magnetic unit 741, the third active magnetic unit 747, the fifth active magnetic unit 749 and/or the sixth active magnetic unit 750 may be arranged on a first side of the first plane 733. The second active magnetic unit 742, the fourth active magnetic unit 748, the first passive magnetic unit 751 and the second passive magnetic unit 752 may be arranged on a second side of the first plane 733.

[00251] Further, FIG. 10C shows a second plane 766 extending through the source support

531. The second plane 766 may be perpendicular to the first plane. During operation of the transportation apparatus 720, the second plane may extend in a vertical direction. During operation, the first plane 733 may be substantially parallel to a substrate receiving area or substrate. The second plane 766 may be substantially perpendicular to the substrate receiving area. The second plane 766 includes a second rotation axis 767 of the deposition source assembly. The second rotation axis 767 may be substantially perpendicular to the first rotation axis. In operation, the second rotation axis 767 may extend along a transversal direction, e.g. substantially parallel to the z-direction, as shown in FIG. 10C.

[00252] As exemplarily shown in FIG. 10C, the first active magnetic unit 741, the second active magnetic unit 742, the fifth active magnetic unit 749 and/or the first passive magnetic unit 751 may be arranged on a first side of the second plane 766. The third active magnetic unit 747, the fourth active magnetic unit 748, the sixth active magnetic unit 750 and the second passive magnetic unit 752 may be arranged on a second side of the second plane 766.

[00253] In operation, the source support 531 shown in FIG. 10C, with the eight magnetic units mounted thereon, may be arranged with respect to a guiding structure including a first portion and a second portion having E-shaped profiles defining recesses as shown in Fig. 10B. The first active magnetic unit 741 and the third active magnetic unit 747 may be at least partially arranged in the first recess 773. The fifth active magnetic unit 749 and the sixth active magnetic unit 750 may be at least partially arranged in the second recess 774. The second active magnetic unit 742 and the fourth active magnetic unit 748 may be at least partially arranged in the third recess 775. The first passive magnetic unit 751 and the second passive magnetic unit 752 may be at least partially arranged in the fourth recess 776.

[00254] Each of the first active magnetic unit, the second active magnetic unit, the third active magnetic unit and the fourth active magnetic unit may be configured for providing a magnetic levitation force acting on the deposition source assembly. Each of these four magnetic levitation forces may partially counteract the weight of the deposition source assembly. The superposition of these four magnetic levitation forces may provide for a superposed magnetic levitation force which fully counteracts the weight of the deposition source assembly, such that a contactless levitation may be provided.

[00255] By controlling the first active magnetic unit, the second active magnetic unit, the third active magnetic unit and the fourth active magnetic unit, the deposition source may be translationally aligned along a vertical direction. Under the control of the controller, the

deposition source may be positioned in a target position along a vertical direction, e.g. the y-direction.

[00256] By controlling, in particular individually controlling, the first active magnetic unit, the second active magnetic unit, the third active magnetic unit and the fourth active magnetic unit, the deposition source assembly may be rotated around the first rotation axis. Similarly, by controlling the units, the deposition source assembly may be rotated around the second rotation axis. The control of the active magnetic units allows controlling the angular orientation of the deposition source assembly with respect to the first rotation axis and the angular orientation with respect to the second rotation axis for aligning the deposition source. Accordingly, two rotational degrees of freedom for angularly aligning the deposition source can be provided.

[00257] The first passive magnetic unit 751 and the second passive magnetic unit 752 are configured for providing a first transversal force T1 and a second transversal force T2, respectively. The fifth active magnetic unit 749 and the sixth active magnetic unit 750 are configured for providing a first opposing transversal force O1 and a second opposing transversal force O2, respectively. In analogy to the discussion provided with respect to FIG. 10A, the first opposing force O1 and the second opposing force O2 counteract the first transversal force T1 and the second transversal force T2.

[00258] By controlling the fifth active magnetic unit 749 and the sixth active magnetic unit 750, and hence controlling the forces T1 and T2, the deposition source may be translationally aligned along a transversal direction, e.g. the z-direction. Under the control of the controller, the deposition source may be positioned in a target position along a transversal direction.

[00259] By individually controlling the fifth active magnetic unit 749 and the sixth active magnetic unit 750, the deposition source assembly may be rotated around a third rotation axis 768, as shown in FIG. 10C. The third rotation axis 768 may be perpendicular to the first rotation axis 734 and/or may be perpendicular to the second rotation axis 767. In operation, the third rotation axis 768 may extend along a vertical direction. The individual control of the fifth active magnetic unit 749 and the sixth active magnetic unit 750 allows controlling the angular orientation of the deposition source assembly with respect to the third rotation axis 768 for angularly aligning the deposition source.

[00260] With exemplary reference to FIGS. 11A-11E, a further transportation apparatus 820 for contactless levitation, transportation and/or alignment of a carrier assembly or a substrate in

a processing system as described herein is described. In the present disclosure, a “carrier assembly” may include one or more elements of the group consisting of: a carrier supporting a substrate, a carrier without a substrate, a substrate, or a substrate supported by a support. Specifically, the carrier assembly is held in a levitating or floating state using magnetic forces instead of mechanical forces. As an example, the further transportation apparatus described herein may have no mechanical means, such as a mechanical rail, supporting the weight of the deposition source assembly. In some implementations, there can be no mechanical contact between the carrier assembly and the rest of the further transportation apparatus at all during levitation, and for example movement, of the carrier assembly in the system.

[00261] According to embodiments of the present disclosure, levitating or levitation refers to a state of an object, wherein the object floats without mechanical contact or support. Further, moving an object refers to providing a driving force, e.g. a force in a direction different than a levitation force, wherein the object is moved from one position to another, different position, for example a different lateral position. For example, an object such as a carrier assembly can be levitated, i.e. by a force counteracting gravity, and can be moved in a direction different from a direction parallel to gravity while being levitated.

[00262] The contactless levitation, transportation and/or alignment of the carrier assembly according to embodiments described herein is beneficial in that no particles are generated due to a mechanical contact between the deposition source assembly and sections of the apparatus, such as mechanical rails, during the transport or alignment of the carrier assembly. Accordingly, the processing system as described herein provides for an improved purity and uniformity of the layers deposited on the substrate, in particular since a particle generation is minimized when using the contactless levitation, transportation and/or alignment.

[00263] A further advantage, as compared to mechanical means for guiding the carrier assembly, is that embodiments described herein do not suffer from friction affecting the linearity and/or precision of the movement of the carrier assembly. The contactless transportation of the carrier assembly allows for a frictionless movement of the carrier assembly, wherein an alignment of the carrier assembly relative to a mask can be controlled and maintained with high precision. Yet further, the levitation allows for fast acceleration or deceleration of the carrier assembly speed and/or fine adjustment of the carrier assembly speed.

[00264] Further, the material of mechanical rails typically suffers from deformations, which may be caused by evacuation of a chamber, by temperature, usage, wear, or the like. Such

deformations affect the position of the carrier assembly, and hence affect the quality of the deposited layers. In contrast, embodiments of the further transportation apparatus 820 as described herein allow for a compensation of potential deformations present in e.g. the guiding structure described herein. In view of the contactless manner in which the carrier assembly is levitated and transported, a contactless alignment of the carrier assembly can be provided. Accordingly, an improved and/or more efficient alignment of the substrate relative to the mask can be provided.

[00265] In particular, the further transportation apparatus 820 is configured for a contactless translation of the carrier assembly along a vertical direction, e.g. the y-direction, and/or along one or more transversal directions, e.g. the x-direction. Further, the further transportation apparatus may be configured for a contactless rotation of the carrier assembly with respect to at least one rotation axis for angularly aligning the carrier assembly, e.g. relative to a mask. Rotation of the carrier assembly with respect to a rotation axis may be provided within an angle range from 0.003 degrees to 3 degrees. Additionally, the further transport apparatus 820 may be configured for an additional mechanical rotation of the carrier assembly, i.e. with contact, with respect to at least one rotation axis for angularly aligning the carrier assembly, e.g. relative to a mask. Mechanical rotation of the deposition source assembly with respect to a rotation axis may be provided within an angle range from 0.0001 degrees to 3 degrees.

[00266] FIG. 11A shows a front view of an exemplary further transportation apparatus 820 in the x-y-plane and FIG. 11C shows a side view in the x-z plane of the further transportation apparatus 820 shown in FIG. 11A. Typically, the further transportation apparatus 820 may be arranged in the process module, particularly in the vacuum process chamber. Additionally, the further transport apparatus may also be provided in at least one further module of the processing system, e.g. in the transfer module 415 and/or the routing module 410 and/or the service module, and/or the mask carrier magazine 320 and or the mask carrier loader 310 and or the first buffer chamber 151 and/or the second buffer chamber and/or the first vacuum swing module 131 and/or further vacuum swing module 132.

[00267] As exemplarily shown in FIGS. 11A to 11E, the further transportation apparatus 820 may include a carrier assembly 880 which can include the substrate 101 to be transported, e.g. in a substrate carrier as described herein. The carrier assembly 880 typically includes a first passive magnetic element 851. As exemplarily shown in FIG. 11A, the further transportation apparatus may include a further guiding structure 870 extending in a carrier assembly transportation direction. The guiding structure includes a plurality of active magnetic elements

875. The carrier assembly 880 is configured to be movable along the further guiding structure 770, as exemplarily indicated with the horizontal arrow in FIG. 11A. The first passive magnetic element 851 and the plurality of active magnetic elements 875 of the further guiding structure 870 are configured for providing a first magnetic levitation force for levitating the carrier assembly 880.

[00268] Further, as exemplarily shown in FIG. 11A, the further transportation apparatus may include a drive structure 890. The drive structure can include a plurality of further active magnetic elements 895. The carrier assembly can include a second passive magnetic element 852, e.g. a bar of ferromagnetic material to interact with the further active magnetic elements 895 of the drive structure 890. Typically, an active magnetic element of the plurality of active magnetic elements 875 provides magnetic force interacting with the first passive magnetic element 851 of the carrier assembly 880. For example, the first passive magnetic element 851 can be a bar or a rod of a ferromagnetic material which can be a portion of the carrier assembly 880. Alternatively, first passive magnetic element may be integrally formed with a substrate support. Further, as exemplarily shown in FIGS. 11A and 11B, typically the carrier assembly 880 includes a second passive magnetic element 852, for example a further bar or further rod of ferromagnetic material, which can be connected to the carrier assembly 880 or be integrally formed with the substrate support.

[00269] According to embodiments described herein, the plurality of active magnetic elements 875 provides for a magnetic force on the first passive magnetic element 851 and, thus, on the carrier assembly 880. Accordingly, the plurality of active magnetic elements 875 levitate the carrier assembly 880. Typically, the further active magnetic elements 895 are configured to drive the carrier within the processing system along a substrate transport direction, for example along the X-direction shown in FIGS. 11A and 11B, i.e. along a first direction. Accordingly, the plurality of further active magnetic elements 895 form the drive structure for moving the carrier assembly 880 while being levitated by the plurality of active magnetic elements 875. The further active magnetic elements 895 interact with the second passive magnetic element 852 to provide a force along the substrate transport direction. For example, the second passive magnetic element 852 can include a plurality of permanent magnets, which are arranged with an alternating polarity. The resulting magnetic fields of the second passive magnetic element 852 can interact with the plurality of further active magnetic elements 895 to move the carrier assembly 880 while being levitated.

[00270] In order to levitate the carrier assembly 880 with the plurality of further active

magnetic elements 895 and/or to move the carrier assembly 880 with the plurality of further active magnetic elements 895, the active magnetic elements can be controlled to provide adjustable magnetic fields. The adjustable magnetic field may be a static or a dynamic magnetic field. According to embodiments, which can be combined with other embodiments described herein, an active magnetic element is configured for generating a magnetic field for providing a magnetic levitation force extending along a vertical direction. According to other embodiments, which can be combined with further embodiments described herein, an active magnetic element may be configured for providing a magnetic force extending along a transversal direction. An active magnetic element, as described herein, may be or include an element selected from the group consisting of: an electromagnetic device; a solenoid; a coil; a superconducting magnet; or any combination thereof.

[00271] FIGS. 11A and 11B show side views of operational states of the further transportation apparatus 820 according to embodiments, which can be combined with other embodiments described herein. As shown, the further guiding structure 870 may extend along a transport direction of the carrier assembly, i.e. the X-direction in FIGS. 11A and 11B. The transport direction of the carrier assembly is a transversal direction as described herein. The further guiding structure 870 may have a linear shape extending along the transport direction. The length of the further guiding structure 870 along the source transportation direction may be from 1 to 30 m. The substrate 101 may be arranged substantially parallel to the drawing plane, e.g. with a deviation of $+15^\circ$. The substrate may be provided in a substrate receiving area during the substrate processing, for example layer deposition process. The substrate receiving area has dimensions, e.g. a length and a width, which are the same or slightly (e.g. 5-20 %) larger than the corresponding dimensions of the substrate.

[00272] During operation of the further transportation apparatus 820, the carrier assembly 880 may be translatable along the further guiding structure 870 in the transportation direction, e.g. the x-direction. FIGS. 11A and 11B show the carrier assembly 880 at different positions along the x-direction relative to the further guiding structure 870. The horizontal arrow indicates a driving force of the drive structure 890. As a result, a translation of the carrier assembly 880 from left to right along the further guiding structure 870 is provided. The vertical arrows indicate a levitation force acting on the carrier assembly.

[00273] The first passive magnetic element 851 may have magnetic properties substantially along the length of first passive magnetic element 851 in the transport direction. The magnetic field generated by the active magnetic elements 875' interacts with the magnetic properties of

the first passive magnetic element 851 to provide for a first magnetic levitation force and a second magnetic levitation force. Accordingly, a contactless levitation, transportation and alignment of the carrier assembly 880 may be provided.

[00274] As shown in FIG. 11A, the carrier assembly 880 is provided at a first position. According to embodiments of the present disclosure, two or more active magnetic elements 875', for example two or three active magnetic elements 875', are activated by a carrier controller 840 to generate a magnetic field for levitating the carrier assembly 880. According to embodiments of the present disclosure, the carrier assembly hangs below the further guiding structure 870 without mechanical contact.

[00275] In FIG. 11A, two active magnetic elements 875' provide a magnetic force, which is indicated by the vertical arrows. The magnetic forces counteract the gravity force in order to levitate the carrier assembly. The carrier controller 840 may individually control the two active magnetic elements 875' to maintain the carrier assembly in a levitating state. Further, one or more further active magnetic elements 895' can be controlled by the carrier controller 840. The further active magnetic elements interact with the second passive magnetic element 852, for example a set of alternating permanent magnets, to generate a driving force indicated by the horizontal arrow. The driving force moves the substrate, for example the substrate supported by the support of the carrier assembly, along the transport direction. As shown in FIG. 11A, the transport direction can be the X-direction. According to some embodiments of the present disclosure, which can be combined with other embodiments described herein, the number of further active magnetic elements 895', which are simultaneously controlled to provide the driving force, is 1 to 3. The movement of the carrier assembly moves the substrate along the transport direction, for example the X-direction. Accordingly, at a first position, the substrate is positioned below the first group of active magnetic elements and at a further, different position, the substrate is positioned below the further, different group of active magnetic elements. The controller controls which active magnetic elements provides a levitation force for a respective position and controls the respective active magnetic elements to levitate the carrier assembly. For example, the levitating force can be provided by subsequent active magnetic elements' while the substrate is moving. According to embodiments described herein, the carrier assembly is handed over from one set of active magnetic elements to another set of active magnetic elements.

[00276] FIG. 11B shows the carrier assembly in a second position, e.g. a processing position, in which the substrate is processed in the process module. In the processing position,

the carrier assembly can be moved to a desired position. The substrate is aligned relative to the mask with the contactless transport system described in the present disclosure.

[00277] In the second position, as exemplarily shown in FIG. 11B, two active magnetic elements 875' provide a first magnetic force indicated by the left vertical arrow and a second magnetic force indicated by right vertical arrow. The carrier controller 840 controls the two active magnetic elements 875' to provide for an alignment in a vertical direction, for example the Y-direction in FIG. 11B. Further, additionally or alternatively, the carrier controller 840 controls the two active magnetic elements 875' to provide for an alignment, wherein the carrier assembly is rotated in the X-Y-plane. Both alignment movements can exemplarily be seen in FIG. 11B by comparing the position of the dotted carrier assembly and the position of the carrier assembly 880 drawn with solid lines.

[00278] The controller may be configured for controlling the active magnetic elements 875' for translationally aligning the carrier assembly in a vertical direction. By controlling the active magnetic elements, the carrier assembly 880 may be positioned into a target vertical position. The carrier assembly 880 may be maintained in the target vertical position under the control of the carrier controller 840. Accordingly, the controller can be configured for controlling the active magnetic elements 875' for angularly aligning the deposition source with respect to a first rotation axis, e.g. a rotational axis perpendicular to a main substrate surface, e.g. a rotational axis extending in a Z-direction in the present disclosure.

[00279] According to embodiments of the further transport apparatus, an alignment of the carrier assembly, particularly a contactless alignment, in a vertical direction (Y-direction) can be provided with an alignment range from 0.1 mm to 3 mm. Further, an alignment precision, particularly a contactless alignment precision, in the vertical direction can be 50 μm or below, for example 1 μm to 10 μm , such as 5 μm . According to embodiments of the present disclosure, a rotational alignment precision, particularly a contactless alignment precision, can be 3° or below.

[00280] According to embodiments of the further transport apparatus, one or more further active magnetic elements 895' can provide a driving force as indicated by the double sided horizontal arrow in FIG. 10B. The controller controls the one or more further active magnetic elements 895' to provide for an alignment in a transport direction, for example the X-direction in FIGS. 10A and 10B. According to embodiments of the present disclosure, an alignment of the carrier assembly in a transport direction (X-direction) can be provided with an alignment

range extending along the length of the guiding structure. Further, an alignment precision, particularly a contactless alignment precision, in the transport direction can be 50 μm or below, for example 5 μm or 30 μm .

[00281] Accordingly, embodiments of the further transportation apparatus provide for levitated carrier assembly movement which allows for a high precision in substrate positioning in a transport direction and/or a vertical direction. Further, the positioning precision of carrier assemblies according to embodiments described herein allow for an improved alignment of a substrate supported by a carrier of a carrier assembly relative to the mask. The alignment can be improved to provide for the desired precision for some mask configurations or can be improved to allow for a reduced complexity of a separate alignment system for some other mask configurations.

[00282] FIGS. 11D and 11E show some alternative configuration possibilities of the further transportation apparatus 820 to provide a substrate orientation being vertical, wherein a small deviation having an absolute value of 15° or smaller can be provided. As exemplarily shown in FIGS. 11D and 11E, the substrate 101 supported by the substrate support 102 can be slightly inclined to face downwardly. Accordingly, particle adherence to the substrate surface during processing of the substrate can be reduced. The carrier assembly shown in FIG. 11D is inclined, i.e. has a slight deviation from the vertical orientation, by providing an additional active magnetic element 876 or a plurality of additional active magnetic elements distributed along the length of the further guiding structure 870, wherein the second passive magnetic element 852 is attracted by the further active magnetic element. Accordingly, the carrier assembly is provided in the levitated state, wherein the lower end of the carrier assembly is pulled sideward by the further active magnetic element. Other elements for pulling the lower end of the carrier assembly sideward without mechanical contact can also be provided.

[00283] According to yet further embodiments, the deviation from the vertical orientation may also be provided by passive magnetic elements, e.g. permanent magnets. For example, the carrier assembly may have a permanent magnet provided as the second passive magnetic element 852 or in addition, e.g. adjacent to, the second passive magnetic element 852. A further permanent magnet can be provided below the permanent magnet. The further permanent magnet and the permanent magnet can be provided with opposing polarity to attract each other. By the attracting force, the carrier assembly can be deflected from the vertical orientation. Further, the attracting force may provide a guiding along the transportation direction. According to yet further embodiments, which can be combined with other embodiments

described herein, a yet further pair of permanent magnets may be provided to provide a guiding force at the upper side of the carrier. Accordingly, one permanent magnet of the second pair of permanent magnets can be provided in an upper region of the carrier assembly, and a corresponding permanent magnet of the second pair of permanent magnets may be provided adjacently in the region of the guiding structure. By attracting forces between the second pair of permanent magnets, a guiding along the transport direction can be provided.

[00284] FIG. 11E shows a further alternative configuration possibility of the further transportation apparatus 820. In particular, in order to provide a substrate orientation of the substrate 101, which is inclined, i.e. which is slightly deviating from the vertical orientation (e.g. by an absolute value of 15° or below) the substrate support 102 is shaped to provide a substrate inclination while the carrier assembly is vertical.

[00285] According to embodiments of the further transportation apparatus, the carrier assembly 880 can include one or more holding devices (not shown) configured for holding the substrate 101 at the substrate support 102. The one or more holding devices can include at least one of mechanical, electrostatic, electrodynamic (van der Waals), electromagnetic and/or magnetic means, such as mechanical and/or magnetic clamps.

[00286] In some implementations, the carrier assembly includes, or is, an electrostatic chuck (E-chuck). The E-chuck can have a supporting surface, for example the substrate support 102 shown in FIGS. 11A to 11E for supporting the substrate 101 thereon. In one embodiment, the E-chuck includes a dielectric body having electrodes embedded therein. The dielectric body can be fabricated from a dielectric material, preferably a high thermal conductivity dielectric material such as pyrolytic boron nitride, aluminum nitride, silicon nitride, alumina or an equivalent material. The electrodes may be coupled to a power source, which provides power to the electrode to control a chucking force. The chucking force is an electrostatic force acting on the substrate to fix the substrate on the supporting surface of the support.

[00287] In some implementations, the carrier assembly 880 includes, or is, an electrodynamic chuck or Gecko chuck (G-chuck). The G-chuck can have a supporting surface for supporting the substrate thereon. The chucking force can be an electrodynamic force acting on the substrate to fix the substrate on the supporting surface.

[00288] As exemplarily described with reference to FIGS. 4A to 4E, a mask 330 can be provided between the deposition source 520 and a substrate 101 which can be supported by a

carrier assembly 880. For example, the mask can be an edge exclusion mask, as shown in FIG. 12A, or can be a shadow mask for depositing a pattern on a substrate, as shown in FIG. 12B. Typically, the mask can be supported by a mask carrier.

[00289] As exemplarily shown in FIG. 12A, typically an edge exclusion mask is configured to cover a portion of the edge of the substrate 101 by providing a mask edge 332. For example, the width 333 of the portion of the substrate 101 can be 10 mm or below, for example 5 mm or below. An open area 334 or opening is provided by the mask edge 332, i.e. is surrounded by the mask edge 332. The partition wall may optionally be provided in the middle of the edge exclusion mask, such that there are two or more openings surrounded by corresponding edges. Yet, the openings are not configured to define pattern features. The openings are configured to define areas of the substrate. For example, the open area 334 of the opening shown in FIG. 12A can be at least 80% of the area of the substrate. For embodiments having two or more openings, each opening has an area of at least 0.1% of the substrate area.

[00290] Further, in FIG. 12A a carrier assembly 880 having the substrate 101 supported thereon is shown in dotted lines. Accordingly, it is to be understood that by employing the further transportation apparatus 820 as described herein, the carrier assembly 880 and, thus, the substrate 101, can be aligned relative to the mask 330.

[00291] FIG. 12B shows a shadow mask 340 including a plurality of small openings 341. For example, the area of the small openings, i.e. the area of one feature of a pattern to be generated, can be 0.01% or below of the substrate area. FIG. 12B shows a carrier assembly 880 having the substrate 101 supported thereon.

[00292] According to some embodiments of the present disclosure, which can be combined with other embodiments described herein, a pre-alignment of the substrate and the mask relative to each other can be provided by the further transportation apparatus 820 which is configured for levitating the substrate without mechanical contact. For example, the pre-alignment can have a precision of 50 μm or below. The precision of such a pre-alignment allows for utilizing further alignment actuators, for example piezoelectric actuators, such as piezoelectric alignment actuators, for conducting a final alignment.

[00293] In particular, according to embodiments which can be combined with any other embodiments described herein, an alignment system 550 as briefly described with reference to FIG. 4A may be provided. With exemplary reference to FIGS 12B and 12 C, typically the

alignment system 550 includes two or more alignment actuators 350, for example four alignment actuators, as exemplarily shown in FIG. 12B. According to some embodiments in which a pre-alignment is conducted, e.g. by utilizing the further transportation apparatus as described above, the alignment actuators can have a reduced complexity as compared to common alignment actuators, which would be utilized without the above-mentioned precision of the pre-alignment. For example, for the pre-alignment the further transportation apparatus as described herein may include rails which are configured to stop a carrier to be aligned in a pre-set position inside the process module. For instance, the mask carrier may be moved into the pre-set position inside the process module and the alignment system 550 may then conduct the fine adjustment of the desired position. Thereafter, locking bolts, e.g. four locking bolts one on each corner of the mask carrier, may move forward to hold the mask carrier. After the mask carrier is positioned, the substrate carrier may be moved into a pre-set position inside the process module. Then the substrate carrier can be aligned, e.g. by the alignment system. When the substrate carrier and the mask carrier are in the correct position, locking bolts may be employed for holding the correct position of the substrate carrier and the mask carrier.

[00294] Further, according to some embodiments which can be combined with any other embodiment described herein, one or more cameras may be installed inside the process module which are configured and arranged such that the alignment of the mask relative to the substrate can be checked, e.g. by monitoring position detection marks provided on the mask carrier and/or the mask and/or the substrate carrier and/or the substrate. For example, the detection marks may be dark dots or holes.

[00295] According to some embodiments, the alignment system 550 can be configured to work from outside the vacuum process chamber, i.e., from the atmospheric side, as exemplarily shown in FIG. 4A. Typically, the alignment system includes a holding arrangement with two or more alignment actuators, which provide a short connection path between the mask carrier and the substrate carrier. In particular, the holding arrangement 900 includes two or more alignment actuators 350 connectable to at least one of the substrate carrier 910 and the mask carrier 335, wherein the holding arrangement 900 is configured to support the substrate carrier 910.

[00296] As exemplarily shown in FIG. 12C, according to some embodiments, a first alignment actuator 350A of the two or more alignment actuators 350 can be configured to move the carrier assembly 880 and the mask carrier 335 relative to each other at least in a first direction Y. Additionally, a second alignment actuator 350B of the two or more alignment actuators may be provided which can be configured to move the carrier assembly 880 and the

mask carrier 335 relative to each other at least in the first direction Y and a second direction X different from the first direction Y. According to some implementations, the first alignment actuator 350A is floating with respect to the second direction X. The term “floating” may be understood as the first alignment actuator 350A allowing a movement of the substrate carrier 910 in the second direction X, e.g., driven by the second alignment actuator 350B.

[00297] Typically, the holding arrangement may further include at least one of a third alignment actuator 350C and a fourth alignment actuator 350D. Accordingly, two or more alignment actuators are configured to move or align the carrier assembly or substrate carrier 910 or mask carrier 335 in, or parallel to, a first plane (e.g., in x-direction and y-direction), and are configured to adjust or change an angular position of the substrate carrier 910 or mask carrier 335 in, or parallel to, the first plane. Thus, the substrate 101 can be aligned with respect to the mask 330, and the quality of the deposited layers can be improved.

[00298] Although not explicitly shown in FIG. 12C, it is to be understood that typically a mask 330, as exemplarily described with reference to FIGS. 12A and 12B, can be attached to the mask carrier 335. As exemplarily shown in FIGS. 12B and 12C, typically the holding arrangement 900 is configured for supporting at least one of the substrate carrier 910 and the mask carrier 335 in a substantially vertical orientation.

[00299] Further, it is to be understood that the two or more alignment actuators can be connected to at least one element of the carrier assembly and the mask carrier 335. As an example, the two or more alignment actuators can be connected to the substrate carrier 910, wherein the two or more alignment actuators are configured to move the substrate carrier 910 relative to the mask carrier 335, wherein the mask carrier 335 can be in a fixed or stationary position. In other examples, the two or more alignment actuators are connected to the mask carrier 335, wherein the two or more alignment actuators are configured to move the mask carrier 335 relative to the substrate carrier 910, wherein the substrate carrier 910 can be in a fixed or stationary position.

[00300] In some implementations, at least one alignment actuator of the two or more alignment actuators is configured to move the substrate 101 and the mask carrier 335 relative to each other in a third direction Z, in particular wherein the third direction is substantially perpendicular to the first plane and/or the substrate surface 103. As an example, the first alignment actuator 350A and the second alignment actuator 350B can be configured to move the substrate carrier 910 or mask carrier 335 in the third direction Z. In some implementations,

a distance between the substrate 101 and the mask 330 can be adjusted by moving the carrier assembly or the substrate carrier 910 or the mask carrier 335 in the third direction Z. As an example, the distance between the substrate 101, or substrate carrier 910, and the mask 330 can be adjusted to be substantially constant in an area of a substrate surface 103 configured for layer deposition thereon. According to some embodiments, the distance can be less than 1 mm, specifically less than 500 micrometers, and more specifically less than 50 micrometers.

[00301] As exemplarily show in FIG. 12C, according to some embodiments, which can be combined with other embodiments described herein, the first alignment actuator 350A and the second alignment actuator 350B are provided at a first edge portion 921 of the substrate carrier and the third alignment actuator 350C and the fourth alignment actuator 350D are provided at a second edge portion 922 of the substrate carrier. In particular, the first alignment actuator 350A, the second alignment actuator 350B, the third alignment actuator 350C and the fourth alignment actuator 350D may be provided in corners or corner regions of the substrate carrier 910, for example, in corners or corner regions of the first edge portion 921 or the second edge portion 922.

[00302] According to some embodiments, which can be combined with other embodiments described herein, the two or more alignment actuators can be electric or pneumatic actuators. The two or more alignment actuators can for example be linear alignment actuators. In some implementations, the two or more alignment actuators can include at least one actuator selected from the group consisting of: a stepper actuator, a brushless actuator, a DC (direct current) actuator, a voice coil actuator, and a piezoelectric actuator. The term “actuator” can refer to motors, e.g., stepper motors. The two or more alignment actuators can be configured to move or position carrier assembly or the substrate carrier, correspondingly the substrate, with a precision of less than about plus/minus 1 micrometer. As an example, the two or more alignment actuators can be configured to move or position the substrate carrier with a precision of about plus/minus 0.5 micrometer, and specifically about 0.1 micrometer, in at least one of the first direction Y, the second direction X, and the third direction Z. In some implementations, moving of the substrate in at least one of the first direction, the second direction and the third direction can be performed by simultaneously or sequentially driving the two or more alignment actuators.

[00303] Accordingly, embodiments of the processing system as described herein are beneficially configured for manufacturing large area display devices, e.g. OLED-devices, with high or even ultra-high resolution.

[00304] Briefly summarized, embodiments of the processing system as described herein are in particular configured for depositing one or more layers, particularly layers including organic materials therein, on a substrate supported by a carrier. The processing system typically includes a load lock chamber 110 for loading a substrate to be processed; a routing module 410 configured for transporting the substrate supported by the carrier; a first vacuum swing module 131 provided between the load lock chamber 110 and the routing module 410; and a process module 510 including a deposition source 520 for depositing material in a vacuum process chamber 540 of the process module, wherein the process module is connected to the routing module. The processing system may further include a service module 610 connected to the process module, wherein the service module 610 is configured such that the deposition source 520 can be transferred from the vacuum process chamber 540 to the service module 610 and from the service module to the vacuum process chamber. Further, the processing system includes an unload lock chamber 116 for unloading the substrate that has been processed. As described herein, the processing system typically includes: a further routing module 412 configured for transporting the substrate supported by the carrier; a mask carrier magazine 320 connected to the further routing module 412, wherein the mask carrier magazine 320 is configured for storing and transporting masks employed during operation of the processing system; a further vacuum swing module 132 provided between the unload lock chamber 116 and the further routing module 412; and a transportation system configured for transporting the carrier between the first vacuum swing module 131 and the further vacuum swing module 132 under vacuum conditions and/or under a controlled inert atmosphere.

[00305] According to embodiments which can be combined with any other embodiments described herein, the deposition source 520 includes an evaporation crucible 521, wherein the evaporation crucible is configured to evaporate the material. Further, the deposition source 520 typically includes a distribution assembly 530 with one or more outlets, wherein the distribution assembly 530 is in fluid communication with the evaporation crucible 521. As described herein, the deposition source typically includes a distribution pipe 533 with a plurality of nozzles 544, wherein each nozzle of the plurality of nozzles is configured for directing a plume 318 of evaporated source material toward the substrate 101. Additionally, the deposition source may include a shaper shielding device 517 including a plurality of apertures 545 wherein at least one aperture of the plurality of apertures 545 is configured to individually shape the plume 318 of evaporated source material emitted from a single associated nozzle.

[00306] Further, according to embodiments which can be combined with any other

embodiments described herein, the processing system includes a transportation apparatus 720 for contactless transportation of the deposition source 520. Typically, the transportation apparatus 720 includes a deposition source assembly 730 including the deposition source 520, a first active magnetic unit 741, and a guiding structure 770 extending in a deposition source transportation direction. The first active magnetic unit and the guiding structure are configured for providing a first magnetic levitation force F1 for levitating the deposition source assembly. Additionally, a further transportation apparatus 820 for contactless levitation, transportation and/or alignment of a carrier assembly may be provided, the further transportation apparatus including: a further guiding structure 870 having a plurality of active magnetic elements 875, wherein the further guiding structure is configured to levitate the carrier; and a drive structure 890 having a plurality of further active magnetic elements 895, wherein the drive structure 890 is configured to drive the carrier assembly along a transport direction without mechanical contact. Further, as described herein, two or more alignment actuators 350 configured to move a carrier assembly 880 and a mask carrier 335 relative to each other may be provided in the processing system.

[00307] FIG. 13B shows a block diagram for illustrating a method 1300 for operating a processing system, particularly a processing system according to embodiments described herein, for depositing one or more layers, particularly layers including organic materials therein, on a substrate supported by a carrier. The method for operating the processing system includes: loading the substrate in the processing system in a horizontal orientation; loading the substrate onto the carrier in a vacuum swing module; rotating the carrier with the loaded substrate in a vertical orientation in the vacuum swing module; transferring the carrier with the loaded substrate through the processing system and into and out of a process module under vacuum conditions; rotating the carrier in a horizontal orientation in a further vacuum swing module; and unloading the substrate from the carrier in the further vacuum swing module in the horizontal orientation.

[00308] In particular, the first block 1310 of the flowchart represents that a substrate is loaded into the processing system as described herein in a horizontal orientation. The second block 1320 of the flowchart represents that the substrate is loaded on a carrier in a horizontal orientation. The third block 1330 of the flowchart represents that the substrate is rotated by rotating the carrier from the horizontal orientation into a vertical orientation, particularly by using a vacuum swing module as described herein. The fourth block 1340 of the flowchart represents that the substrate is transferred - by transferring the carrier with the substrate in the

vertical orientation - through the processing system, e.g. through one or more process modules as described herein. In particular, transferring the carrier through the processing system may include employing the transportation system as described herein which can be provided in some or all of the modules and chambers of the processing system as described herein. After processing the substrate, the carrier having the substrate thereon is rotated from the vertical orientation to the horizontal orientation, which is represented by the fifth block 1350 of the flowchart. Then the substrate is unloaded in the horizontal orientation in the step which is represented by the sixth block 1360 of the flowchart. Accordingly, it is to be understood that the processing system as described herein may beneficially be used for depositing one or more layers, particularly including organic materials, e.g. for manufacturing of OLED devices.

[00309] Further to the embodiments described above, it is to be understood that the processing system typically includes several drive units, e.g. to move the deposition source, the service flange, and the rotation unit of the routing module. In particular, the rotation drive for the deposition source may be provided inside the source cart and can be configured to turn the deposition source from a home position to an applicable process position. As described with reference to FIGS. 11A to 11C, the source cart typically uses the magnetic levitation system to move the source forwards and backwards inside the process module. The service flange, as exemplarily described with reference to FIGS. 8A and 8B, is typically installed on top of a service flange rotor which may include a rotation drive and drive belt configured for turning the service flange from the service position to the process module and back to the service position. Further, as described with reference to FIGS. 9A and 9B, a rotation drive provided in the routing module is typically configured to turn the mask carrier and/or the substrate carrier such that the mask carrier and/or the substrate carrier can be transported into the applicable process module.

[00310] Additionally, it is to be understood that embodiments of the processing system as described herein may be provided with a vacuum system which includes one or more of the components selected from the group consisting of: fore-vacuum pumps; dry vacuum pumps; high-vacuum pumps; e.g. cryogenic (cryo) pumps which may use very cold surfaces inside to condense gases and remove those gases from the system; venting devices, e.g. valves, for venting the vacuum chambers; particle filters through which the venting gas, e.g. compressed dry air, may enter the vacuum chamber; and a pressure measurement system which is configured for measuring and displaying the current pressures of the individual modules and chambers of the processing system as well as for controlling and monitoring respective

pumping stations by the pressures of the individual modules and chambers.

[00311] Further, it is to be understood that embodiments of the processing system as described herein typically include an electrical system which is configured to supply power to the control devices, such as a hard real time server (HRTS) and a virtual system interface (VSI), as well as to the powered devices of the processing system, e.g. heaters or evaporation cathodes. Typically, devices of the electrical system are arranged in different cabinets, e.g. supply and distribution cabinets which are installed near the processing system and control cabinets which can be attached to the respective modules or chambers.

[00312] Moreover, it is to be understood that typically embodiments of the processing system as described herein may include a cooling water supply; a pneumatic supply, and a vent gas supply. Typically, the process module and the organic triple source are supplied with cooling water. In particular, the processing system may include main supply line for cooling water from which via individual cooling water distribution units the subsystems of each module may be supplied with cooling water. According to some implementations, additional water supply boxes may be provided for the process modules. Further, pneumatic valve assemblies and flow controllers may be provided in each individual cooling water circuit to control and monitor the cooling water supply. The pneumatic supply is typically operated with pressurized gas, e.g. compressed dry air or nitrogen, and is configured to pneumatically operate the valves and pumps of the water supply, the gate valves, and the vent gas equipment. According to typical implementations, the pneumatic supply includes a main supply line in which a pressure from 6 bar to 8 bar may be set at a main input regulator. A maintenance unit may forward the pressurized gas to respective valve units provided at the individual modules. The valve units contain electrically operated pilot valves that control the pressurized gas flow through the pneumatic-driven components.

[00313] In view of the embodiments of the processing system as described herein it is to be understood that the processing system allows for a stable evaporation rate, e.g. of about $\pm 5\%$ or below on a time scale of one week or above. This can particularly be provided by the improved maintenance conditions. Further, embodiments of the processing system as described herein allow for a refill of organic material in an evaporation crucible without breaking vacuum and even without stopping processing. The maintenance and/or refill of one evaporation source can be conducted independent of the operation of another evaporation source. This improves the cost of ownership (CoO) as source maintenance and re-filling thereof is a bottleneck in many other OLED manufacturing systems. In other words, a high system uptime by having no need

to vent the substrate handling or deposition chamber during routine maintenance or during mask exchange can significantly improve the CoO. As described above, one reason for this improvement is the maintenance vacuum chamber and/or other components associated with the maintenance vacuum chamber described herein, wherein maintenance and pre-conditioning of the evaporation source in a separate chamber can be provided.

[00314] Further, the embodiments of the processing system as described herein are configured for vertical substrate processing which allows for a small footprint of the processing systems, particularly when several processing modules are provided as exemplarily described with reference to FIG. 1A. In particular, vertical substrate processing allows for a good scalability for current and future substrate size generations. Accordingly, embodiments of the processing system as described herein allow for coating several layers of organic material on two or more substrates, particularly on large area substrates.

[00315] Yet further, a movable and turntable evaporation source within the process module as described herein allows for a continuous or almost continuous coating with high material utilization. Accordingly, embodiments described herein allow for a high evaporation source efficiency (>85%) and a high material utilization (at least 50% or above) by using a scanning source approach with 180° turning mechanism to coat two substrates in an alternating way with a process module. The source efficiency takes into consideration material losses occurring due to the fact that the vapor beams extend over the size of the large area substrates in order to allow for a uniform coating of the entire area of the substrate which is to be coated. The material utilization additionally considers losses occurring during idle times of the evaporation source, i.e. times where the evaporation source cannot deposit the evaporated material on a substrate.

[00316] Moreover, according to embodiments described herein, a combination of the translational movement of an evaporation source, e.g. a linear vapor distribution showerhead, and the rotation of the evaporation source allows for a high evaporation source efficiency and a high material utilization for OLED display manufacturing. In order to achieve good reliability, yield rates, and high masking precision, typically the mask and the substrate remain stationary during processing of the substrate in a process module as described herein. Accordingly, the processing system as described herein provides for reducing the idle time compared to conventional processing systems in which, after each deposition, the substrate needs to be exchanged including a new alignment step of the mask and the substrate relative to each other. Further, during the idle time, the source is wasting material. Accordingly, having a second

substrate in a deposition position and readily aligned with respect to the mask as described herein reduces the idle time and increases the material utilization.

[00317] Accordingly, in view of the above, embodiments of the processing system as described herein and the methods therefore are improved compared to conventional processing systems, particularly with respect to high throughput and low costs for manufacturing display devices, e.g. OLED display devices, on large area substrates.

CLAIMS

1. A processing system (100) for depositing one or more layers, particularly layers including organic materials therein, on a substrate supported by a carrier, the processing system comprising:

a first vacuum swing module (131) configured for rotating a first substrate from a horizontal state into a vertical state;

a first buffer chamber (151) connected to the first vacuum swing module (131);

a routing module (410) connected to the first buffer chamber (151), wherein the routing module is configured for transporting the first substrate to a processing arrangement (1000) comprising a deposition source;

a second buffer chamber (152) connected to the routing module (410), and

a further vacuum swing module (132) connected to the second buffer chamber (152), wherein the further vacuum swing module (132) is configured for rotating a second substrate from a vertical state into a horizontal state; and

wherein the first buffer chamber (151) is configured for buffering the first substrate received from the first vacuum swing module (131) in a first substrate transport direction and for buffering a third substrate received from the routing module (410) in a second substrate transport direction, and

wherein the second buffer chamber (152) is configured for buffering a second substrate received from the further vacuum swing module (132) in the second substrate transport direction and for buffering a fourth substrate received from the routing module (410) in the first substrate transport direction.

2. The processing system according to claim 1, wherein the first buffer chamber (151) comprises a first switch track (161) configured for shifting the first substrate and/or the third substrate transversal to the first substrate transport direction.

3. The processing system according to claims 1 or 2, wherein the second buffer chamber (152) comprises a second switch track (162) configured for shifting the second substrate and/or the fourth substrate transversal to the second substrate transport direction.

4. The processing system according to any of claims 1 to 3, wherein the routing module (410) is configured to rotate the first substrate received from the first buffer chamber (151) such that the first substrate can be loaded into the processing arrangement (1000) in a loading direction which is different from the first substrate transport direction, particularly wherein the loading direction is perpendicular to the first substrate transport direction.
5. The processing system according to claim 4, wherein the routing module (410) is configured to receive the fourth substrate from the processing arrangement (1000) in an unloading direction which is different from the loading direction, particularly wherein the loading direction is opposite to the unloading direction.
6. The processing system according to any of claims 1 to 5, wherein the first substrate transport direction is opposite to the second substrate transport direction.
7. The processing system according to any of claims 1 to 6, wherein gate valves (115) are provided between the first vacuum swing module (131) and the first buffer chamber (151), between the first buffer chamber (151) and the routing module (410), between the routing module (410) and processing arrangement (1000), between the routing module (410) and the second buffer chamber (152), and between the second buffer chamber (152) and the further vacuum swing module (132).
8. Method for loading and unloading a substrate to a processing arrangement (1000) of a processing system (100), particularly a processing system according to any of claims 1 to 7, the method comprising:
 - transporting a first substrate in a first substrate transport direction from a first vacuum swing module into a first buffer chamber;
 - buffering the first substrate and a third substrate received from a routing module in a second substrate transport direction in the first buffer chamber;
 - shifting the first substrate and the third substrate transversal to the first substrate transport direction in the first buffer chamber;
 - transporting the third substrate from the first buffer chamber into the first vacuum swing module;

transversally back-shifting the first substrate in the first buffer chamber;

transporting the first substrate in the first substrate transport direction from the first buffer chamber into the routing module;

rotating the first substrate in the routing module such that the first substrate can be loaded in a loading direction into the processing arrangement connected to the routing module;

loading the first substrate from the routing module into the processing arrangement;

unloading a fourth substrate from the processing arrangement into the routing module;

rotating the fourth substrate in the routing module such that the fourth substrate can be transported in the first substrate transport direction from the routing module into a second buffer chamber connected to the routing module;

transporting the fourth substrate in the first substrate transport direction into the second buffer chamber;

shifting the fourth substrate transversal to the first substrate transport direction in the second buffer chamber;

transporting a second substrate in the second substrate transport direction from a further vacuum swing module into the second buffer chamber;

transversally back-shifting the fourth substrate and the second substrate in the second buffer chamber; and

transporting the fourth substrate from the second buffer chamber into the further vacuum swing module.

9. A processing system (100) for depositing one or more layers, particularly layers including organic materials therein, on a substrate supported by a carrier, the processing system comprising:

a load lock chamber (110) for loading a substrate to be processed;

a routing module (410) configured for transporting the substrate supported by the carrier;

a first vacuum swing module (131) provided between the load lock chamber (110) and the routing module (410); and

a process module (510) comprising a deposition source (520) for depositing material in a vacuum process chamber (540) of the process module, wherein the process module is connected to the routing module;

a service module (610) connected to the process module, wherein the service module (610) is configured such that the deposition source (520) can be transferred from the vacuum process chamber (540) to the service module (610) and from the service module to the vacuum process chamber;

an unload lock chamber (116) for unloading the substrate that has been processed;

a further routing module (412) configured for transporting the substrate supported by the carrier;

a mask carrier magazine (320) connected to the further routing module (412), wherein the mask carrier magazine (320) is configured for storing and transporting masks employed during operation of the processing system;

a further vacuum swing module (132) provided between the unload lock chamber (116) and the further routing module (412); and

a transportation system configured for transporting the carrier between the first vacuum swing module (131) and the further vacuum swing module (132) under vacuum conditions and/or under a controlled inert atmosphere.

10. The processing system (100) according to any of claims 1 to 7 or 9, wherein the deposition source (520) comprises:

an evaporation crucible (521), wherein the evaporation crucible is configured to evaporate the material; and

a distribution assembly (530) with one or more outlets, wherein the distribution assembly (530) is in fluid communication with the evaporation crucible (521).

11. The processing system (100) according to any of claims 1 to 7 or 9 to 10, further comprising a transportation apparatus (720) for contactless transportation of the deposition source (520), wherein the transportation apparatus (720) comprises a deposition source assembly (730), comprising the deposition source (520), a first active magnetic unit (741); and

a guiding structure (770) extending in a deposition source transportation direction, wherein the first active magnetic unit and the guiding structure are configured for providing a first magnetic levitation force (F1) for levitating the deposition source assembly.

12. The processing system (100) according to any of claims 1 to 7 or 9 to 11, further comprising:

a further transportation apparatus (820) for contactless levitation, transportation and/or alignment of a carrier assembly, the further transportation apparatus (820) comprising:

a further guiding structure (870) having a plurality of active magnetic elements (875), wherein the further guiding structure is configured to levitate the carrier; and

a drive structure (890) having a plurality of further active magnetic elements, wherein the drive structure (890) is configured to drive the carrier assembly along a transport direction without mechanical contact; and

two or more alignment actuators (350) configured to move a carrier assembly (880) and a mask carrier (335) relative to each other.

13. The processing system (100) according to any of claims 1 to 7 or 9 to 12, wherein the deposition source comprises a distribution pipe (533) with a plurality of nozzles (544), wherein each nozzle of the plurality of nozzles is configured for directing a plume (318) of evaporated source material toward the substrate (101); and

a shaper shielding device (517) comprising a plurality of apertures (545) wherein at least one aperture of the plurality of apertures (545) is configured to individually shape the plume (318) of evaporated source material emitted from a single associated nozzle.

14. The processing system (100) according to any of claims 1 to 7 or 9 to 13, wherein the deposition source comprises a measurement outlet (535) for providing evaporated material to a measurement assembly for measuring a deposition rate of the evaporated material of the deposition source, the measurement assembly comprising an oscillation crystal for measuring the deposition rate, and a holder for holding the oscillation crystal, wherein the holder comprises a material having a thermal conductivity k above $k=30 \text{ W/(mK)}$.

15. A method of operating a processing system, particularly a processing system according to any of claims 1 to 7 or 9 to 14, for depositing one or more layers, particularly layers including organic materials therein, on a substrate supported by a carrier, the method comprising:

loading the substrate in the processing system in a horizontal orientation;

loading the substrate onto the carrier in a vacuum swing module;

rotating the carrier with the loaded substrate in a vertical orientation in the vacuum swing module;

transferring the carrier with the loaded substrate through the processing system and into and out of a process module under vacuum conditions;

rotating the carrier in a horizontal orientation in a further vacuum swing module; and

unloading the substrate from the carrier in the further vacuum swing module in the horizontal orientation.

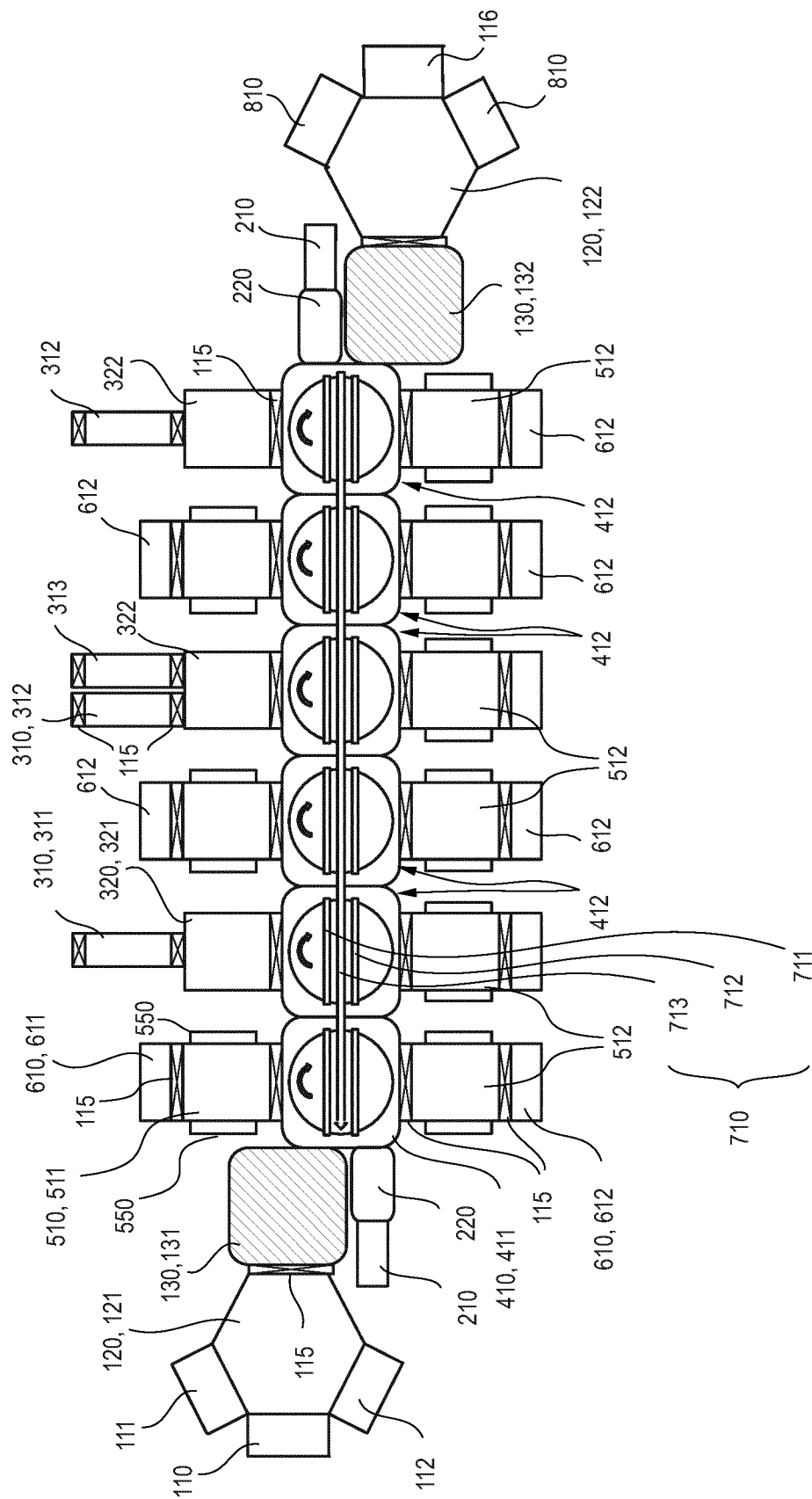
100

FIG. 1A

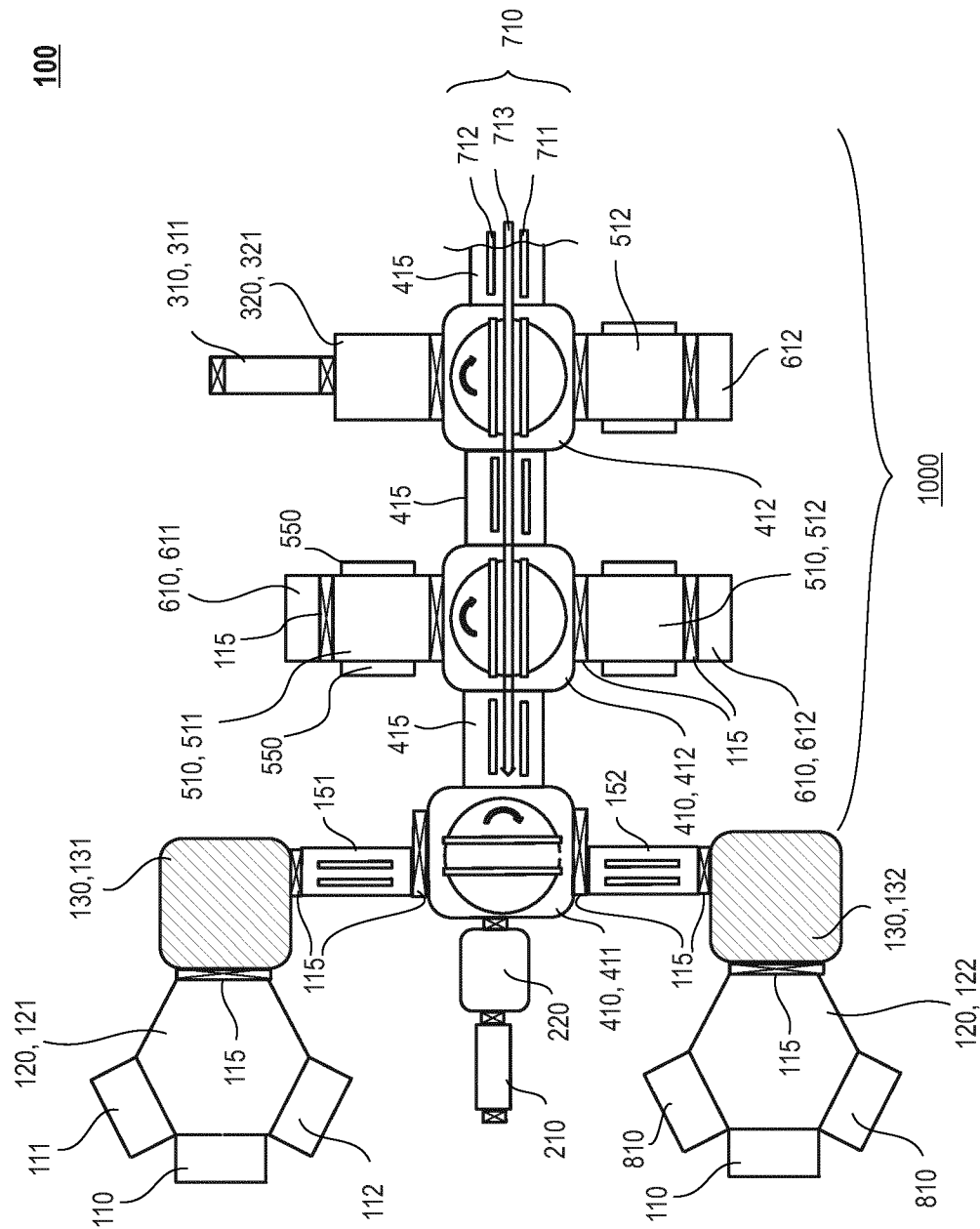


FIG. 1B

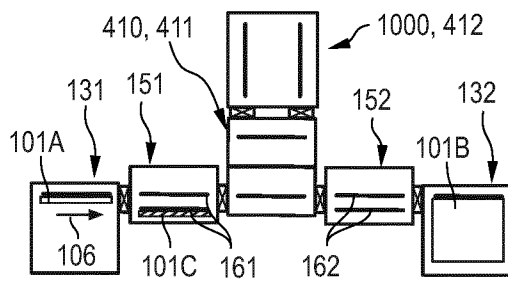


FIG. 2A

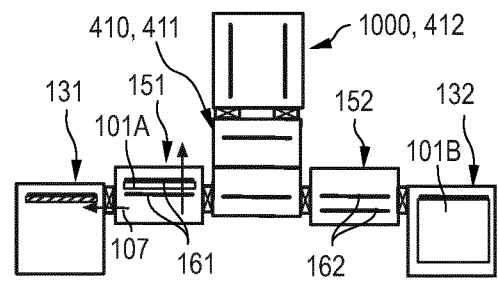


FIG. 2B

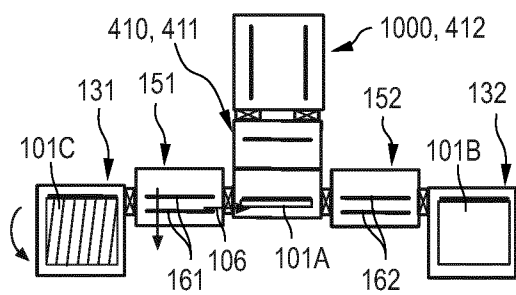


FIG. 2C

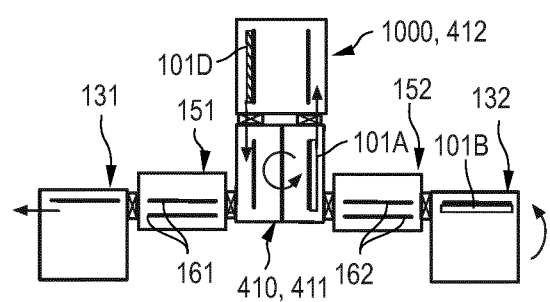


FIG. 2D

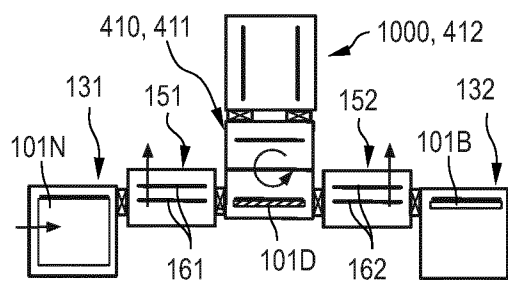


FIG. 2E

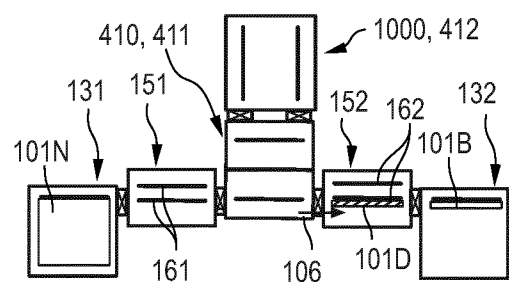


FIG. 2F

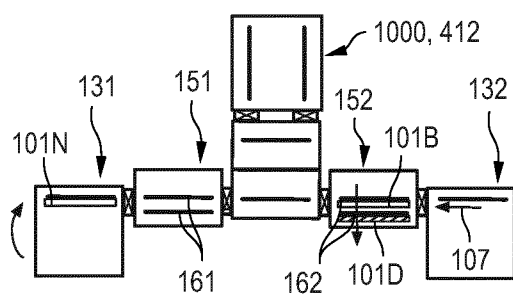


FIG. 2G

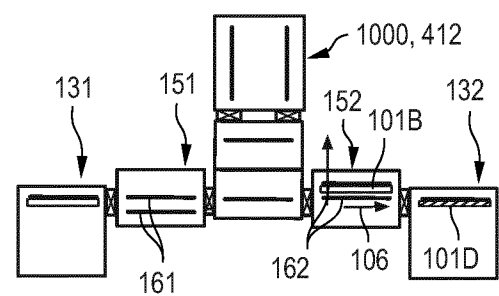


FIG. 2H

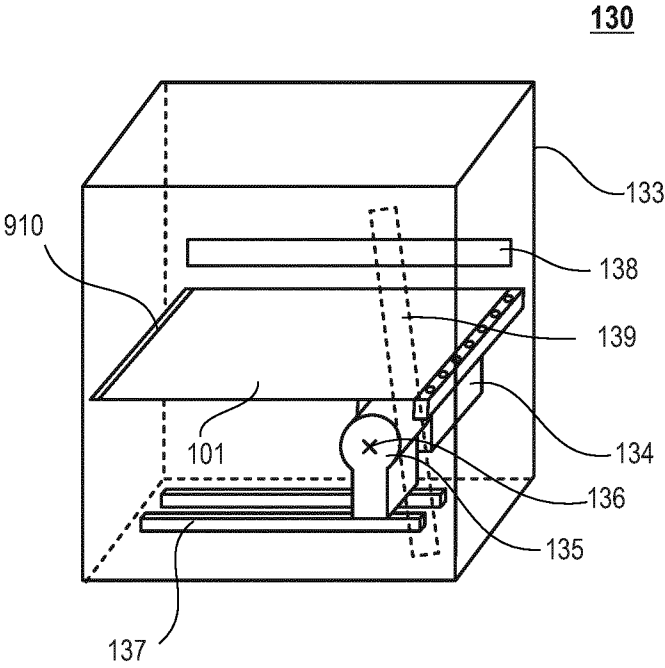


FIG. 3A

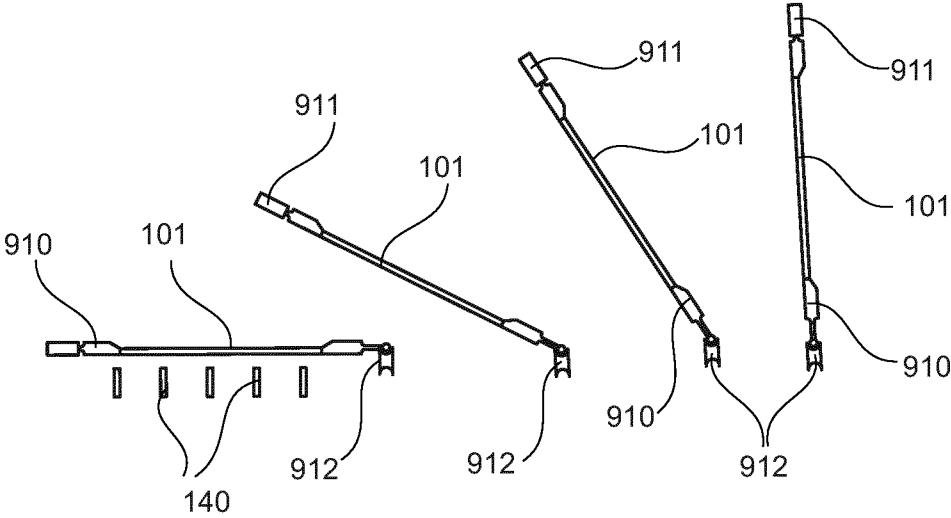


FIG. 3B

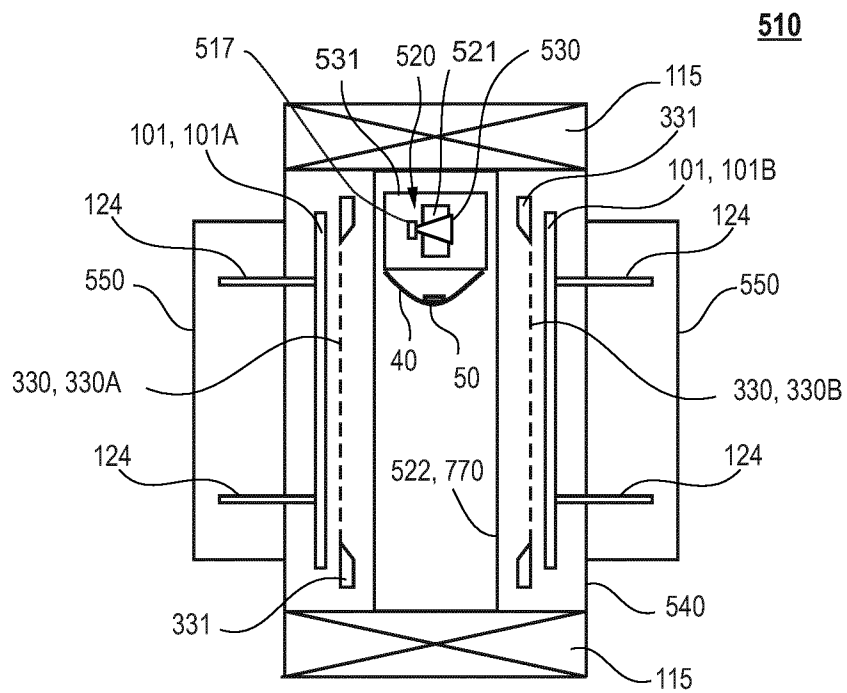


FIG. 4A

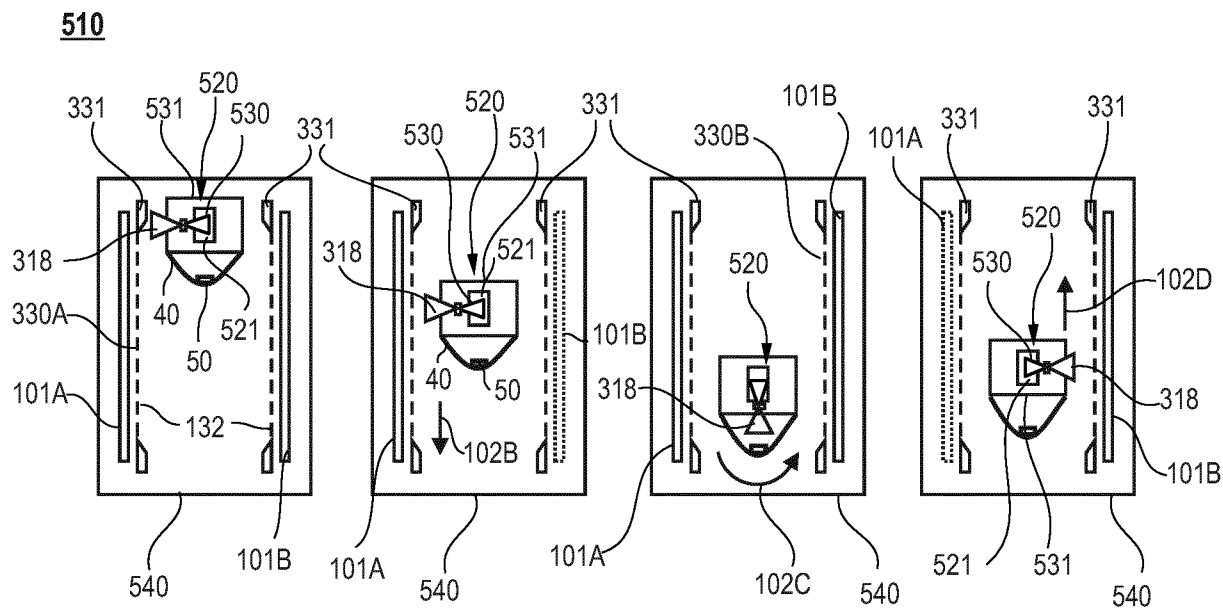


FIG. 4B

FIG. 4C

FIG. 4D

FIG. 4E

6/16

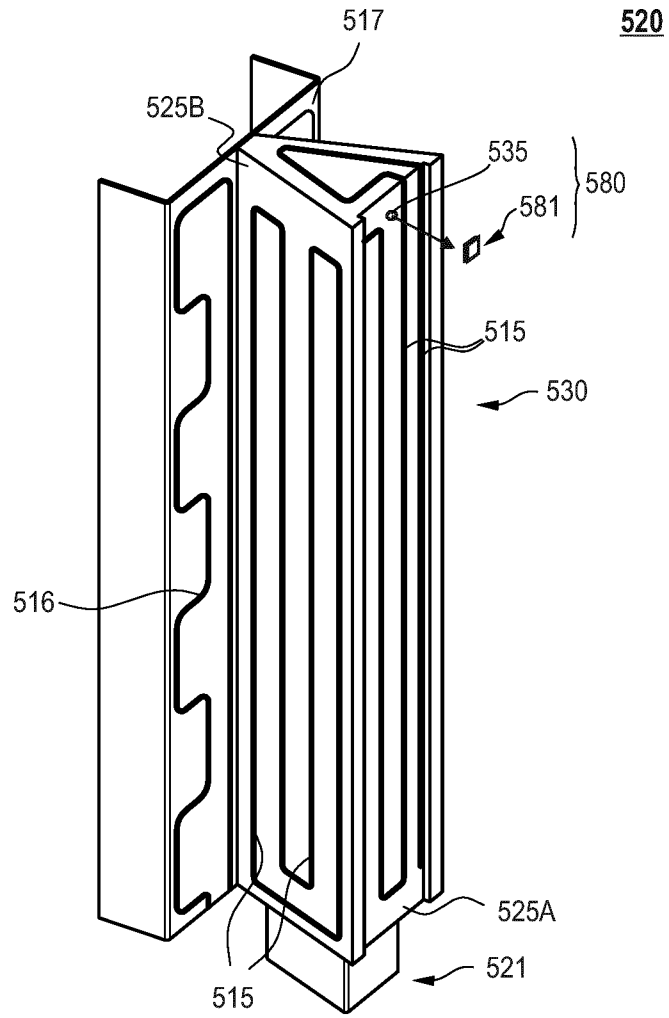


FIG. 5A

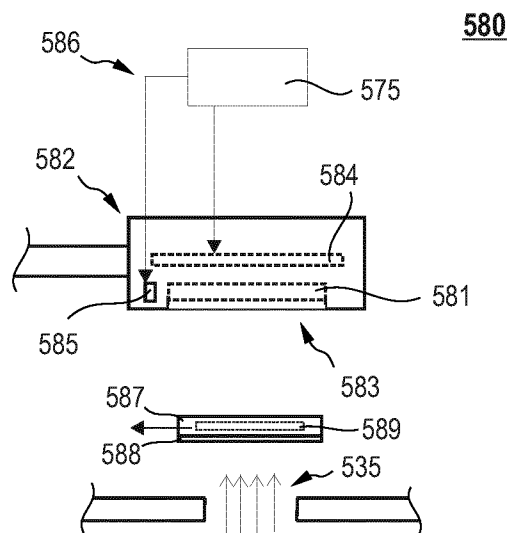


FIG. 5B

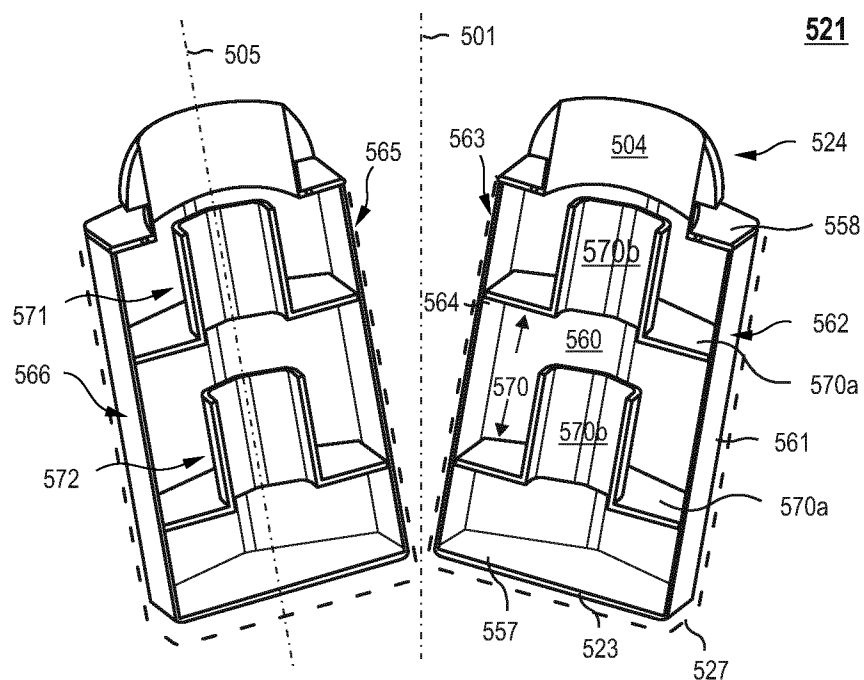


FIG. 6A

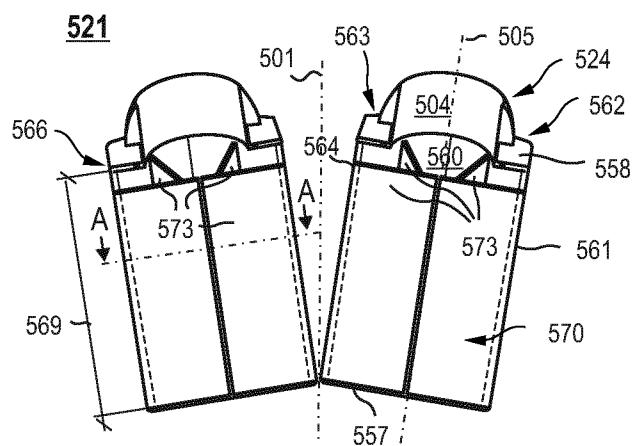


FIG. 6B

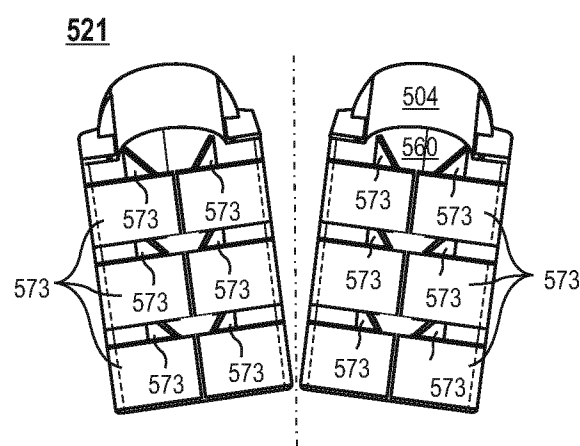


FIG. 6C

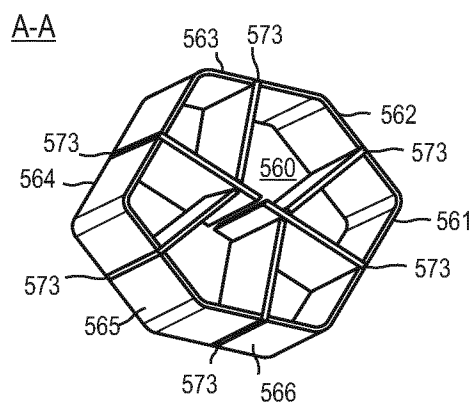


FIG. 6D

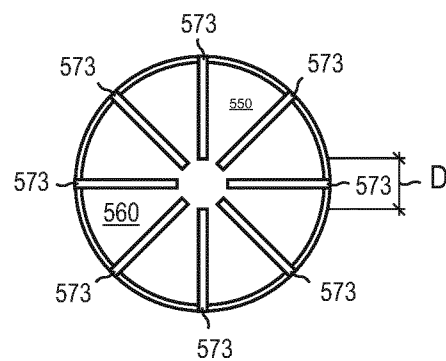


FIG. 6E

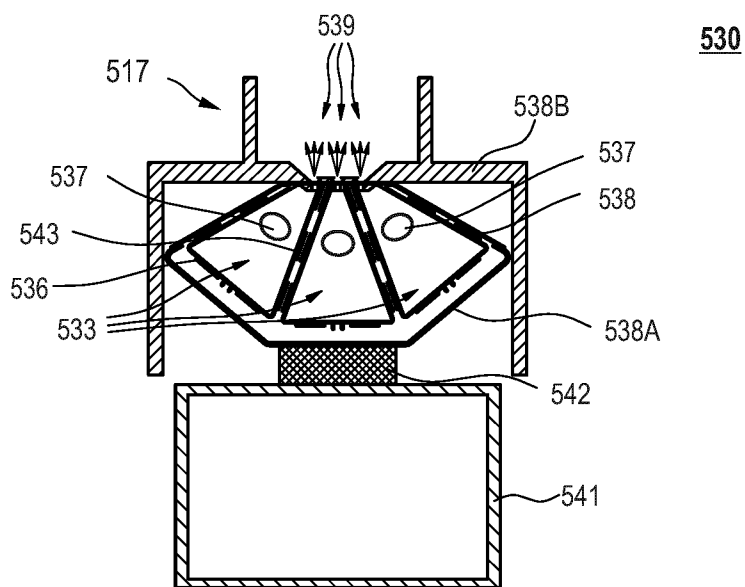


FIG. 7A

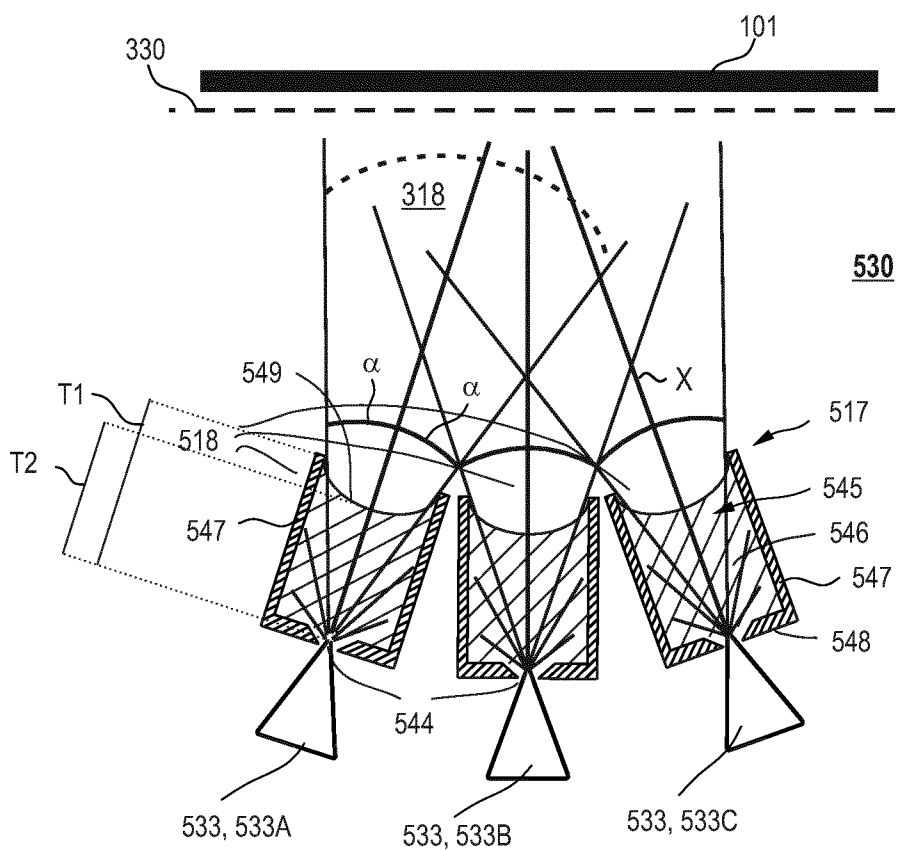


FIG. 7B

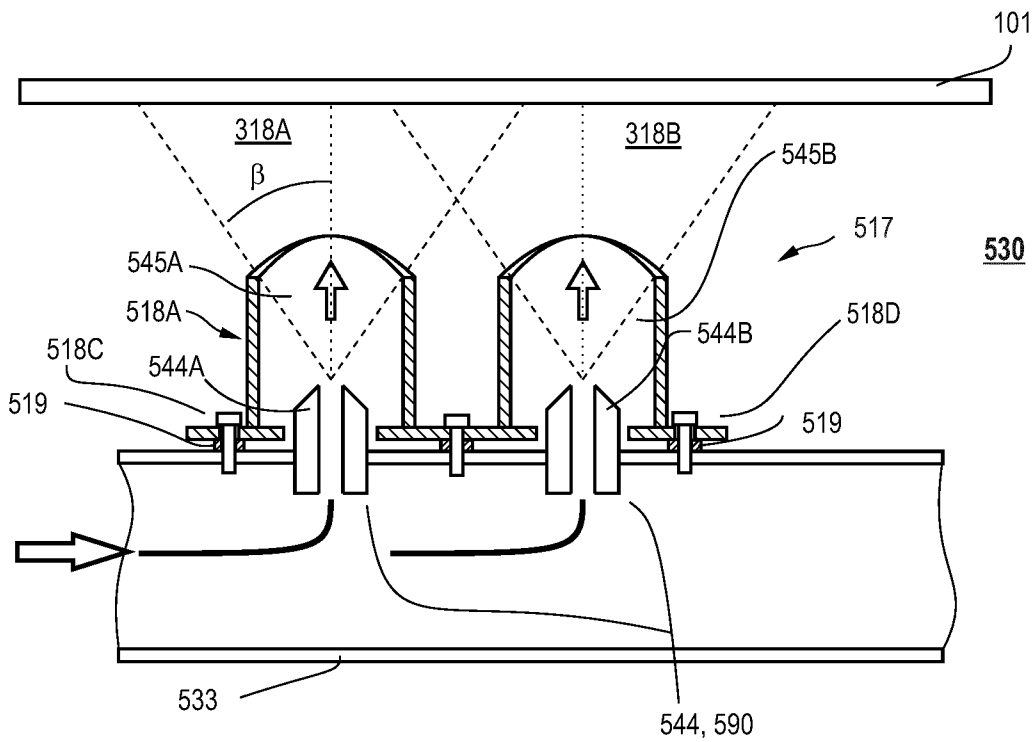


FIG. 7C

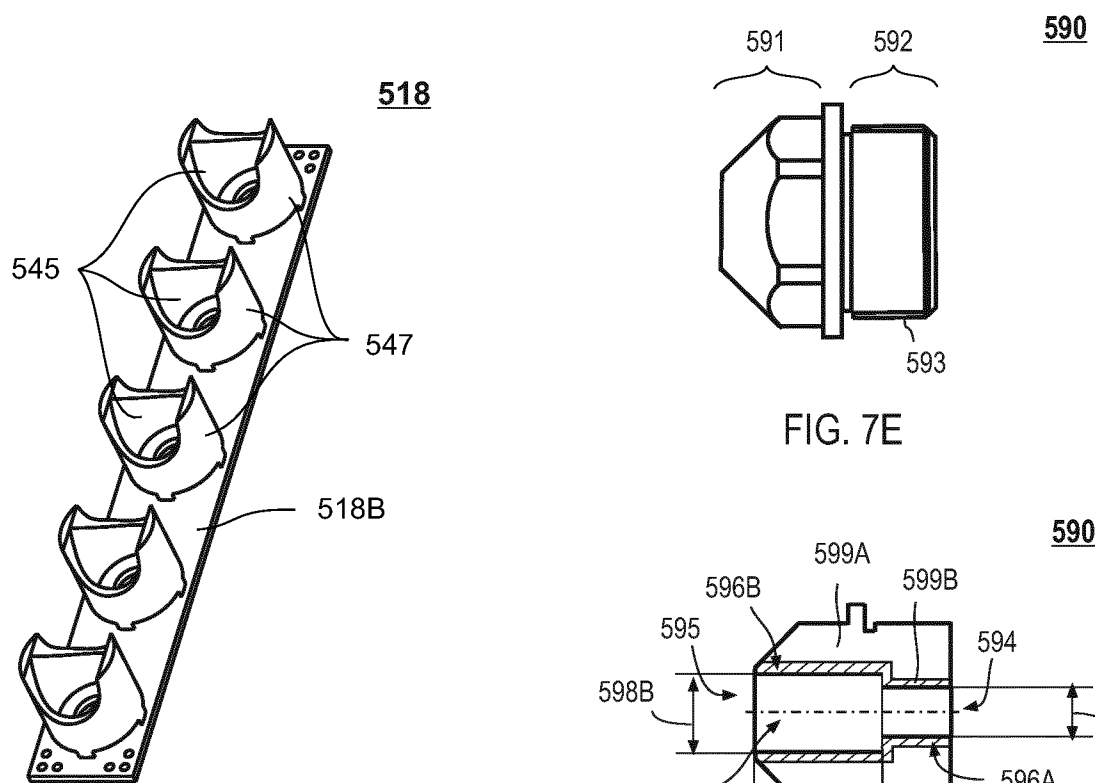


FIG. 7D

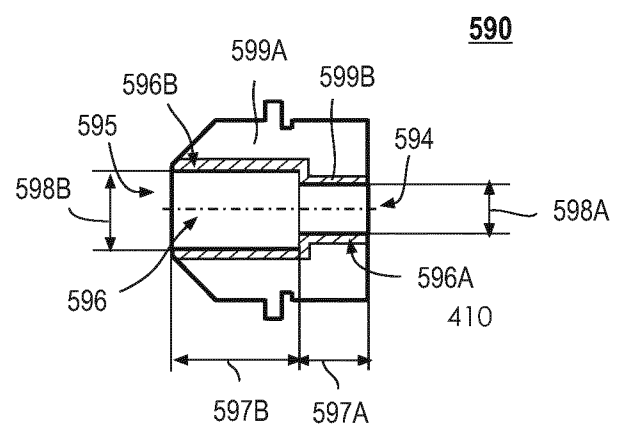


FIG. 7F

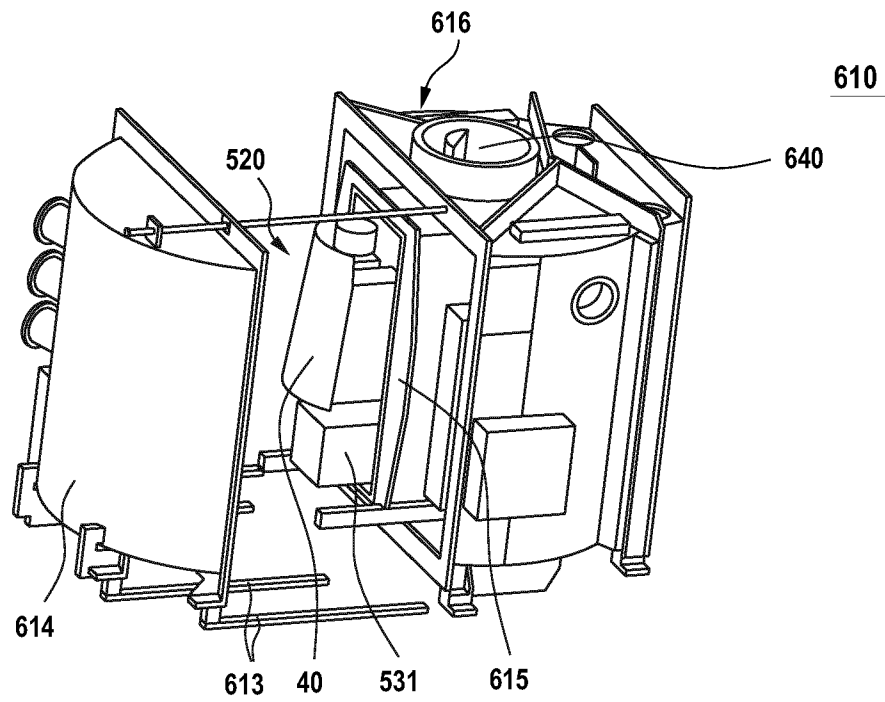


FIG. 8A

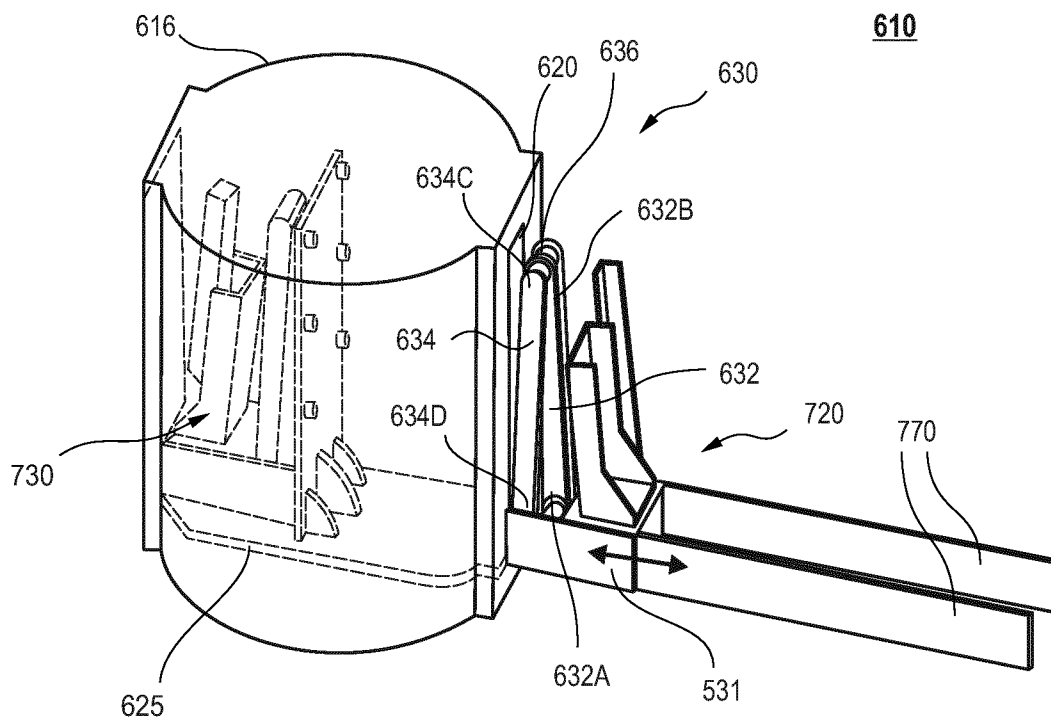


FIG. 8B

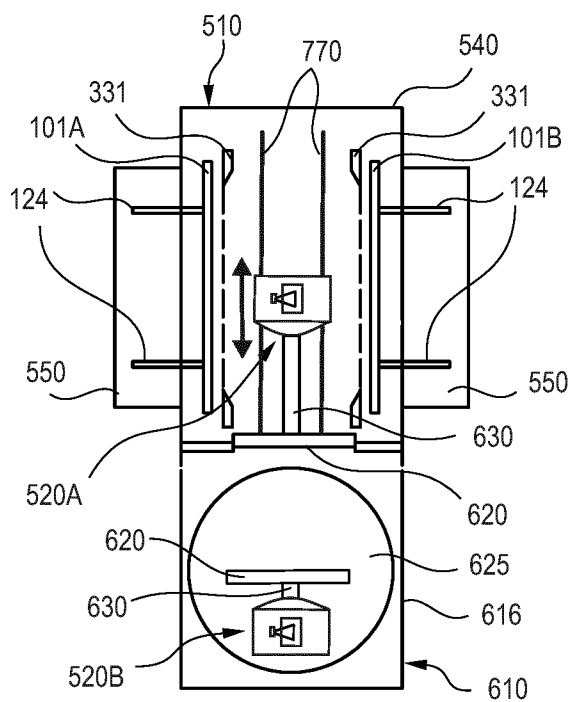


FIG. 8C

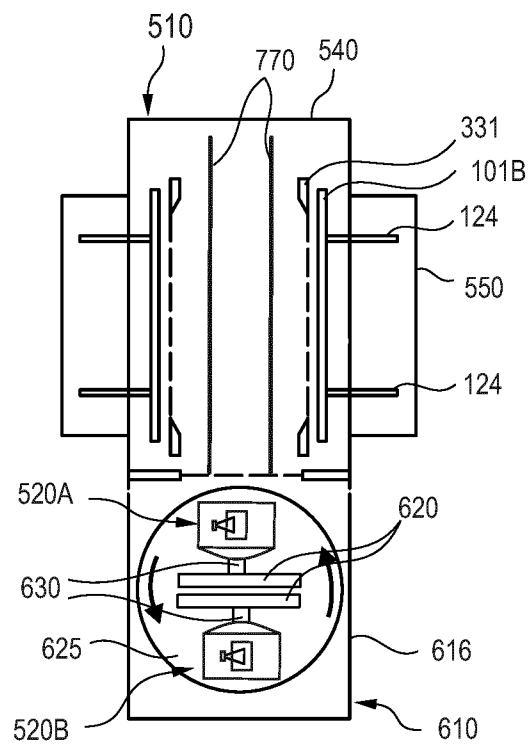


FIG. 8D

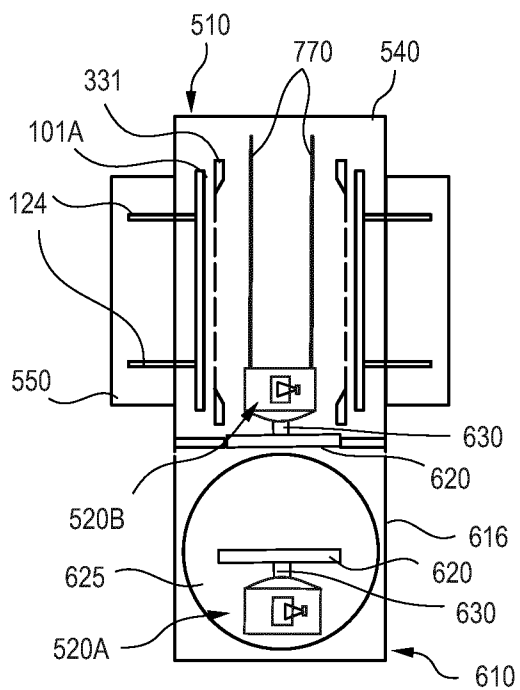


FIG. 8E

410

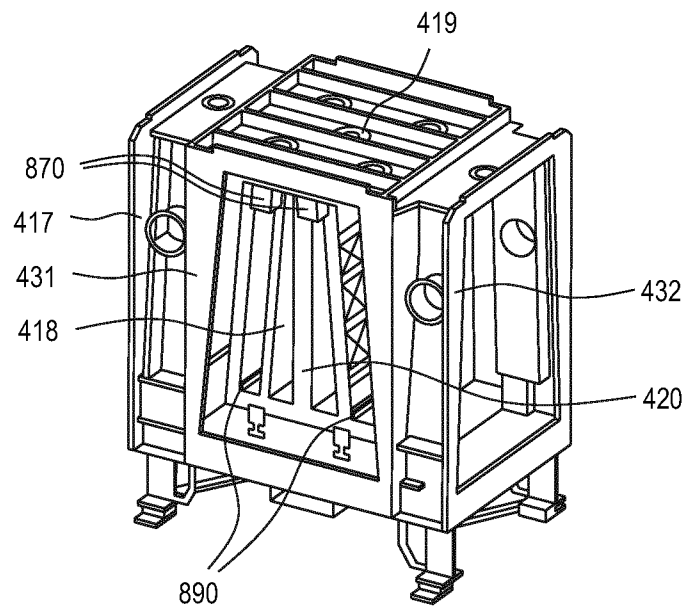


FIG. 9A

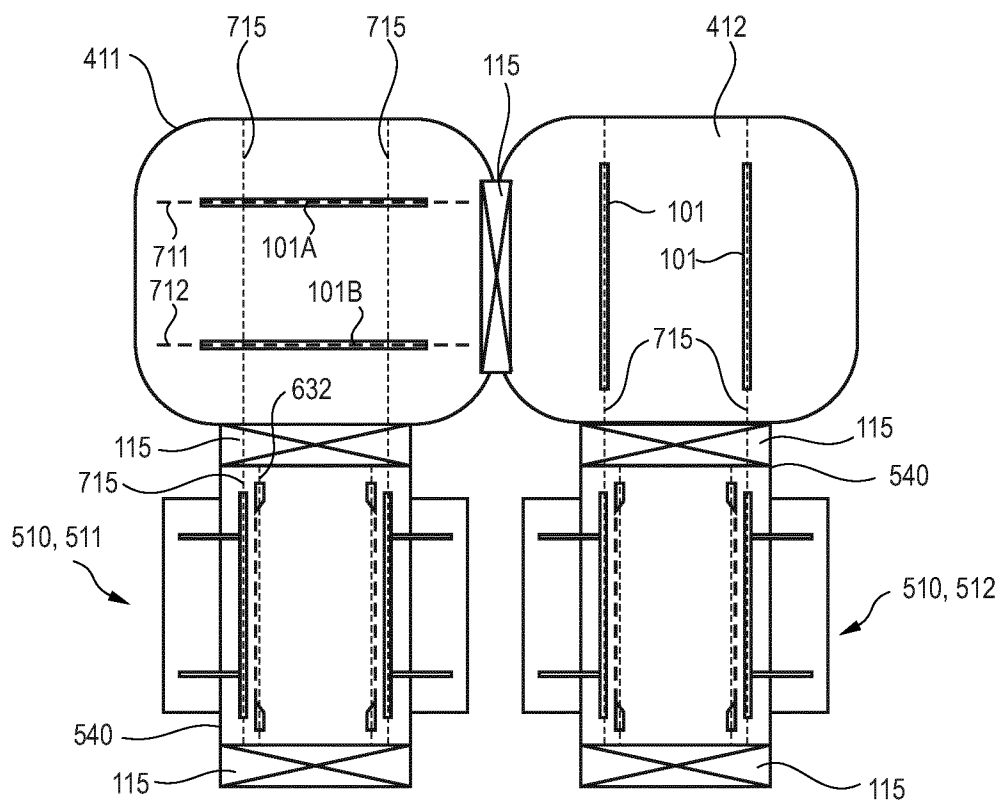
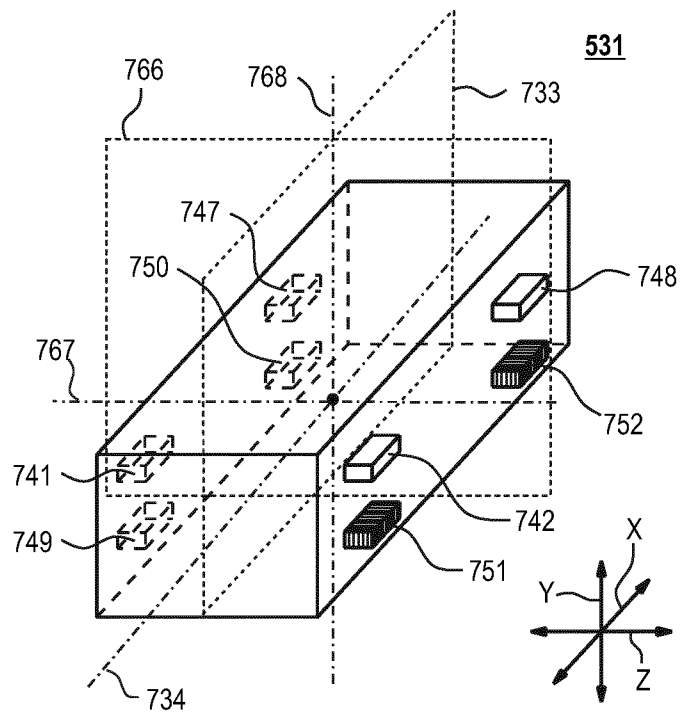
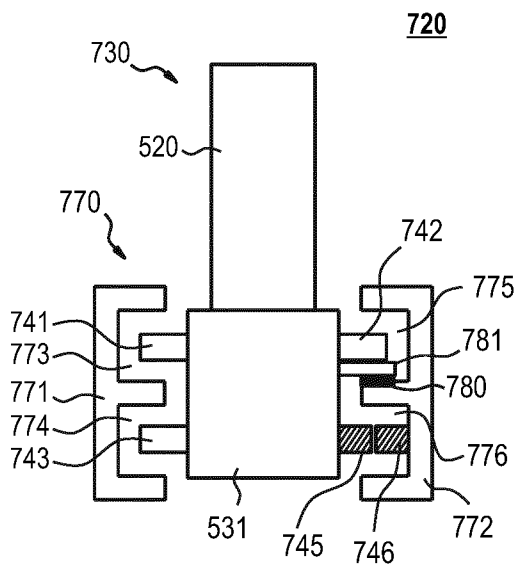
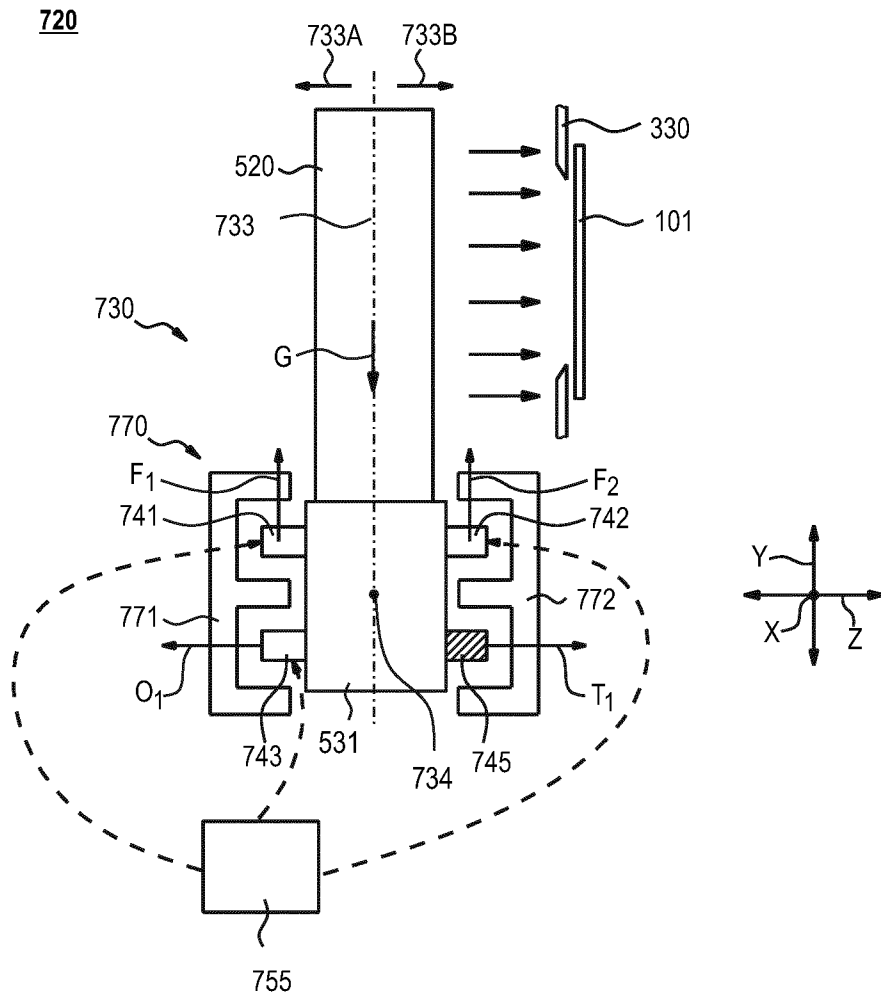


FIG. 9B



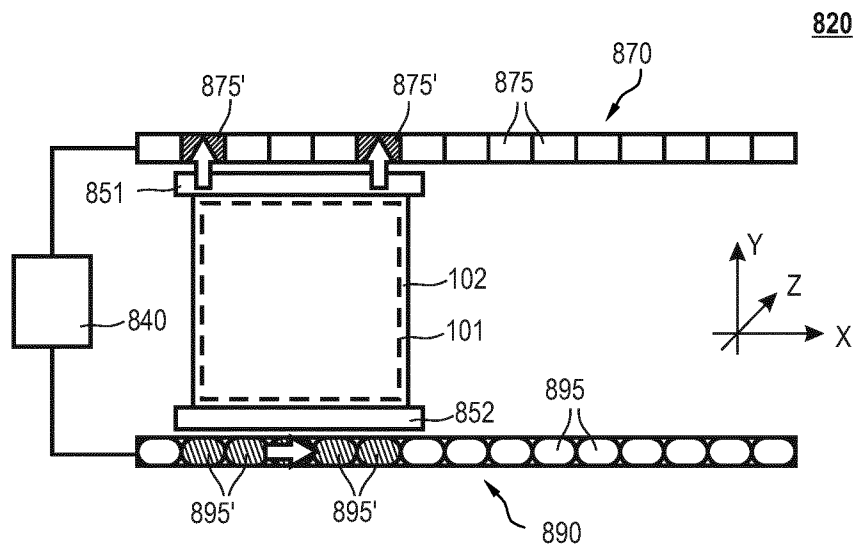


FIG. 11A

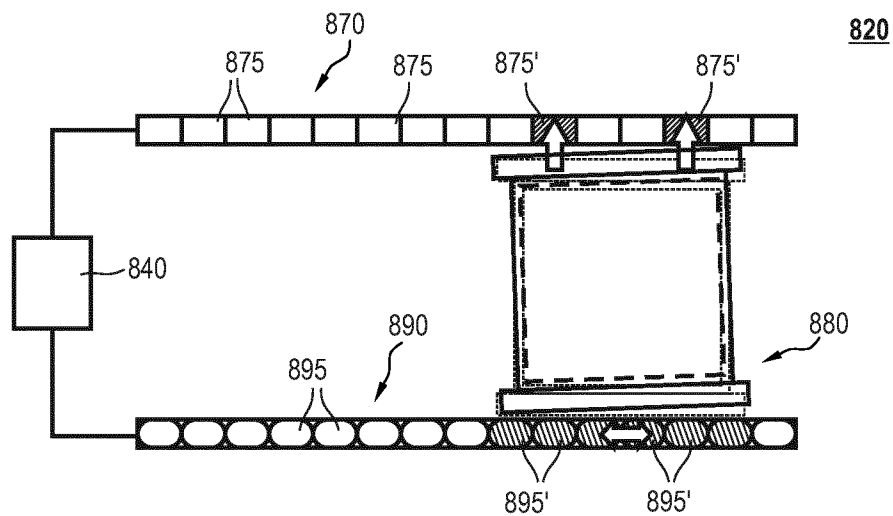


FIG. 11B

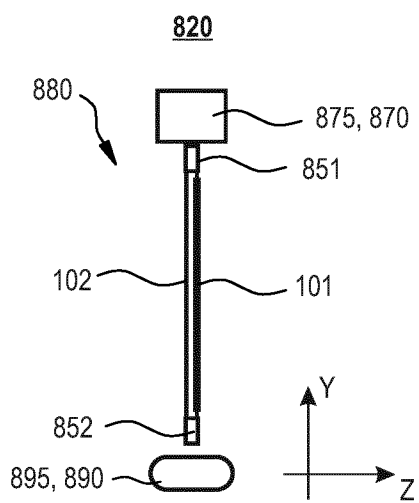


FIG. 11C

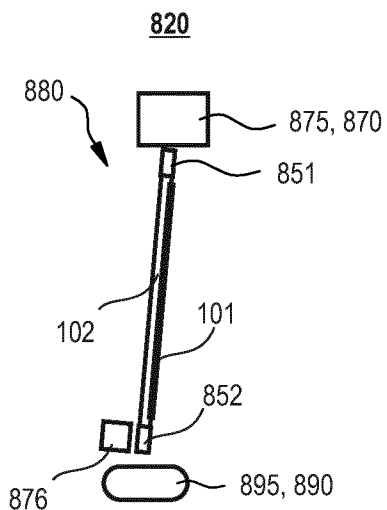


FIG. 11D

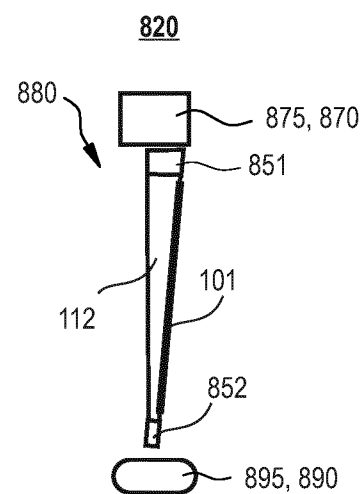


FIG. 11E

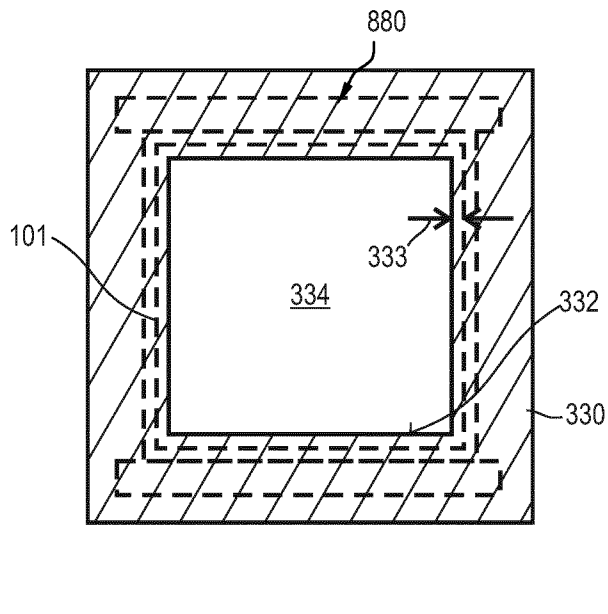


FIG. 12A

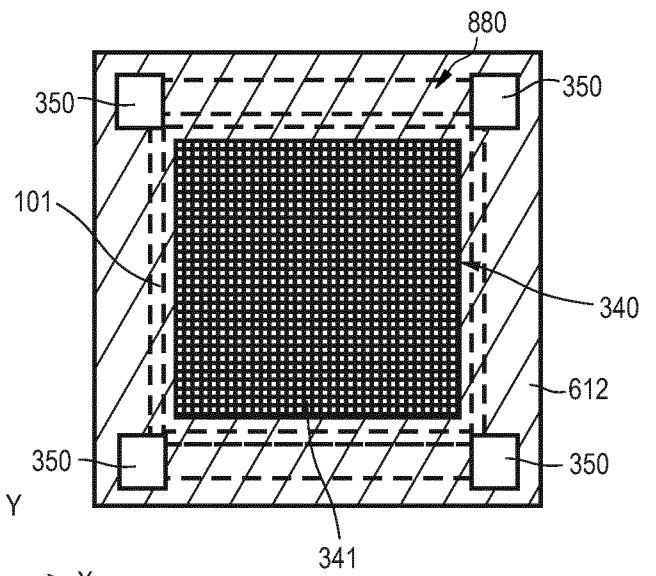


FIG. 12B

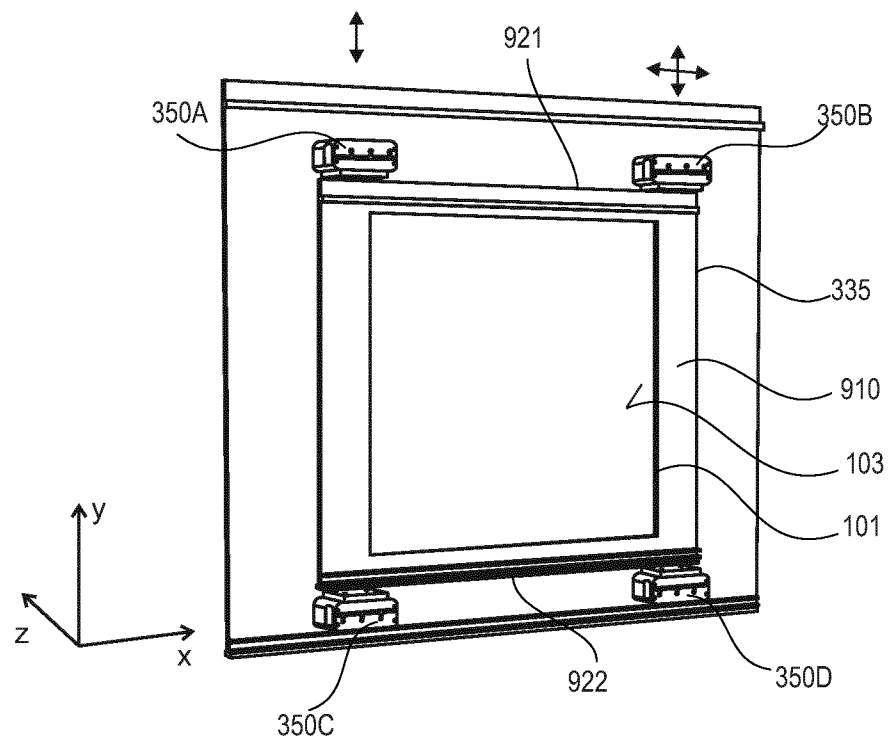


FIG. 12C

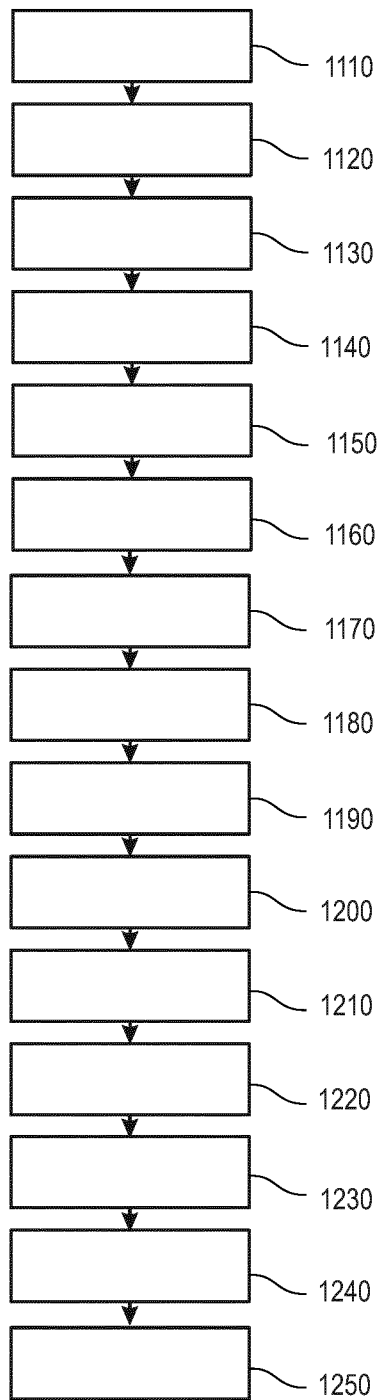
1100

FIG. 13A

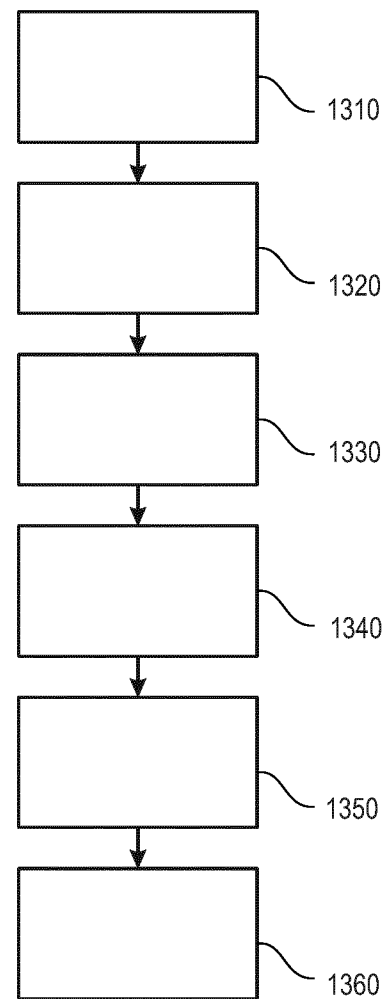
1300

FIG. 13B

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/081027

A. CLASSIFICATION OF SUBJECT MATTER

INV. C23C14/24 C23C14/50 C23C14/56 C23C14/04 C03C17/02
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C23C C03C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EP0-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2015/139776 A1 (APPLIED MATERIALS INC [US]; BANGERT STEFAN [DE]; DIEGUEZ-CAMPO JOSE MA) 24 September 2015 (2015-09-24)	15
A	paragraphs [0085] - [0097]; figure 10 -----	1-9
X	WO 2015/117638 A1 (APPLIED MATERIALS INC.) 13 August 2015 (2015-08-13)	9
A	paragraphs [0031], [0106] - [0118]; figures 3, 11 -----	1-8
A	US 2004/206307 A1 (BOROSON MICHAEL L [US] ET AL) 21 October 2004 (2004-10-21)	1
	paragraphs [0161] - [0163]; figure 6 -----	



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

19 June 2017

Date of mailing of the international search report

25/08/2017

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
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Authorized officer

Ekhult, Hans

INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2016/081027

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-9, 15(completely); 10-14(partially)

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-9, 15(completely); 10-14(partially)

Processing systems, method for loading and unloading and method of operating a processing system.

2. claims: 10-14(partially)

Processing system with crucible and distribution assembly.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2016/081027

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2015139776 A1	24-09-2015	CN 106133183 A EP 3119919 A1 JP 2017509796 A KR 20160135353 A TW 201602373 A US 2017092899 A1 WO 2015139776 A1	16-11-2016 25-01-2017 06-04-2017 25-11-2016 16-01-2016 30-03-2017 24-09-2015
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US 2004206307 A1	21-10-2004	CN 1542994 A JP 2004319513 A KR 20040090922 A TW 200505034 A US 2004206307 A1	03-11-2004 11-11-2004 27-10-2004 01-02-2005 21-10-2004