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(54) **Title**: NOZZLE FOR A MATERIAL SOURCE ARRANGEMENT USED IN VACUUM DEPOSITION

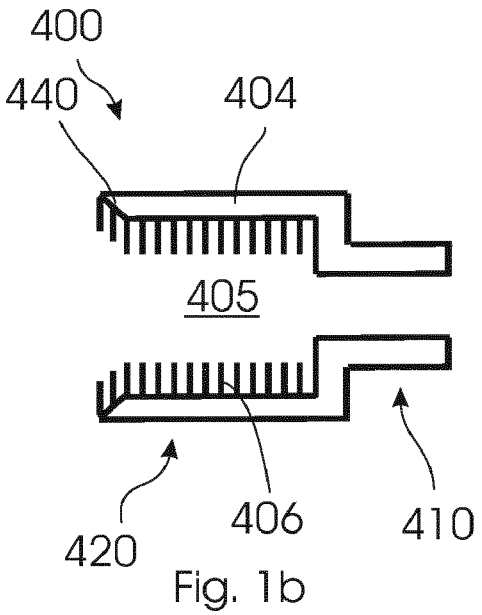


Fig. 1b

(57) **Abstract**: A nozzle (400) for being connected to a distribution pipe (106; 106a; 106b) for guiding evaporated material from a material source (102; 102a; 102b) into a vacuum chamber (110) is described. The nozzle includes a nozzle inlet (401) for receiving the evaporated material, a nozzle outlet (403) for releasing the evaporated material to the vacuum chamber (110), and a nozzle passage (402) between the nozzle inlet (401) and the nozzle outlet (403) along a length direction (460) of the nozzle (400). The nozzle passage (402) has a passage wall (404) surrounding a passage channel (405). Further, the nozzle (400) comprises at least two fins (406) extending into the passage channel (405). Further, a material source arrangement having such a nozzle, a vacuum deposition system with a material source arrangement, and a method for depositing evaporated material are provided.

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NOZZLE FOR A MATERIAL SOURCE ARRANGEMENT USED IN VACUUM DEPOSITION

TECHNICAL FIELD

[0001] Embodiments of the present disclosure relate to a nozzle for a material source arrangement, a material source arrangement, a vacuum deposition system and a method for depositing material on a substrate. Embodiments of the present disclosure particularly relate to a nozzle for guiding evaporated material to a vacuum chamber, a material source arrangement including a vacuum chamber, and a method for depositing a material on a substrate in a vacuum chamber.

BACKGROUND

[0002] Organic evaporators are a tool for the production of organic light-emitting diodes (OLED). OLEDs are a special type of light-emitting diode 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 angles possible with OLED displays is greater than that of traditional LCD displays because OLED pixels directly emit light and do not use a back 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 such a manner as to form a matrix display panel having individually energizable pixels. The OLED is generally placed between two glass panels, and the edges of the glass panels are sealed to encapsulate the OLED therein.

[0003] There are many challenges encountered in the manufacture of such display devices. OLED displays or OLED lighting applications include a stack of several organic materials, which are for example evaporated in a vacuum. The organic materials are deposited in a subsequent manner through shadow masks. For the fabrication of OLED stacks with high efficiency, the co-deposition or co-evaporation of two or more materials, e.g. host and dopant, leading to mixed/doped layers is beneficial. Further, it has to be considered that there are several process conditions for the evaporation of the very sensitive organic materials.

[0004] For depositing the material on a substrate, the material is heated until the material evaporates. Pipes guide the evaporated material to the substrates through outlets or nozzles. In the past years, the precision of the deposition process has been increased, e.g. for being able to provide smaller and smaller pixel sizes. In some processes, masks are used for defining the pixels when the evaporated material passes through the mask openings. However, shadowing effects of a mask, the spread of the evaporated material and the like make it difficult to further increase the precision and the predictability of the evaporation process.

[0005] In view of the above, it is an object of embodiments described herein to provide a nozzle, a material deposition arrangement, a vacuum deposition system, and a method for depositing material on a substrate that overcomes at least some of the problems in the art.

SUMMARY

[0006] In light of the above, a nozzle for evaporated material, a material source arrangement, a vacuum deposition system, and a method for depositing material on a substrate according to the independent claims are provided.

[0007] According to one embodiment, a nozzle for being connected to a distribution pipe for guiding evaporated material from a material source into a vacuum chamber is provided. The nozzle includes a nozzle inlet for receiving the evaporated material, a nozzle outlet for releasing the evaporated material to the vacuum chamber, and a nozzle passage between the nozzle inlet and the nozzle outlet along a length direction of the nozzle. The nozzle passage has a passage wall surrounding a passage channel. The nozzle further comprises at least two fins extending into the passage channel.

[0008] According to a further embodiment, a material source arrangement for depositing a material on a substrate in a vacuum deposition chamber is provided. The material source arrangement includes a distribution pipe being configured to be in fluid communication with a material source providing the material to the distribution pipe. The material source arrangement further includes a nozzle according to embodiments described herein.

[0009] According to a further embodiment, a vacuum deposition system is provided. The vacuum deposition system includes a vacuum deposition chamber and a material source arrangement according to embodiments described herein in the vacuum chamber. The vacuum deposition chamber further includes a substrate support for supporting the substrate during deposition.

[0010] According to a further embodiment, a method for depositing a material on a substrate in a vacuum deposition chamber is provided. The method includes evaporating a material to be deposited in a crucible; providing the evaporated material to a distribution pipe being in fluid communication with the crucible; and guiding the evaporated material through a nozzle having a passage wall surrounding a passage channel between a nozzle inlet and a nozzle outlet to the vacuum deposition chamber. Guiding the evaporated material through the nozzle includes guiding the evaporated material past at least two fins extending into the passage channel.

[0011] Embodiments are also directed at apparatuses for carrying out the disclosed methods and include apparatus parts for performing each described method step. The method steps may be performed by way of hardware components, a computer programmed by appropriate software, by any combination of the two or in any other manner. Furthermore, embodiments are also directed at methods for operating the described apparatus. It includes method steps for carrying out every function of the apparatus.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] So that the manner in which the above recited features of the present disclosure can be understood in detail, a more particular description of embodiments, briefly summarized

above, may be had by reference to some embodiments. The accompanying drawings relate to embodiments and are described in the following:

Fig. 1a shows a schematic view of a nozzle according to embodiments described herein;

Fig. 1b shows a schematic view of a nozzle according to a further embodiment described herein;

Fig. 1c shows a schematic top view of the nozzle shown in Fig. 1b;

Fig. 2 shows a schematic view of a nozzle with three stages according to embodiments described herein;

Fig. 3 shows a schematic view of a nozzle with three stages according to embodiments described herein;

Fig. 4a shows a schematic view of a nozzle with an additional absorber stage according to embodiments described herein;

Fig. 4b shows a schematic view of a nozzle with an additional absorber plate according to embodiments described herein;

Figs. 5a to 5f show a schematic view of a nozzle according to embodiments described herein and details of the nozzle according to embodiments described herein;

Fig. 6a shows a diagram of the material distribution of a material deposition arrangement according to embodiments described herein;

Fig. 6b shows a diagram of the material distribution of a deposition arrangement of another system;

Fig. 7 shows a schematic diagram of a comparison of the distribution of evaporated material on a substrate of another

system and of a nozzle according to embodiments described herein;

Fig. 8 shows a schematic side view of a material source arrangement according to embodiments described herein;

Fig. 9 shows a vacuum deposition system according to embodiments described herein;

Figs. 10a and 10b show schematic views of distribution pipes and nozzles of a material source arrangement according to embodiments described herein; and

Fig. 11 shows a flow chart of a method for depositing material on a substrate according to embodiments described herein.

DETAILED DESCRIPTION OF EMBODIMENTS

[0013] Reference will now be made in detail to various embodiments, 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. Generally, only the differences with respect to individual embodiments are described. Each example is provided by way of explanation and is not meant as a limitation. 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.

[0014] As used herein, the term "fluid communication" may be understood in that two elements being in fluid communication can exchange fluid via a connection, allowing fluid to flow between the two elements. In one example, the elements being in fluid communication may include a hollow structure, through which the fluid may flow. According to some embodiments, at least one of the elements being in fluid communication may be a pipe-like element.

[0015] Furthermore, in the following description, a material deposition arrangement or material source arrangement (both terms may be used synonymously herein) may be understood as an arrangement providing a material to be deposited on a substrate. In particular, the material source arrangement may be configured for providing material to be deposited on a substrate in a vacuum chamber, such as a vacuum deposition chamber or system. According to some embodiments, the material source arrangement may provide the material to be deposited on the substrate by being configured to evaporate the material to be deposited. For instance, the material deposition arrangement may include an evaporator or a crucible, which evaporates the material to be deposited on the substrate, and a distribution pipe, which, in particular, releases the evaporated material in a direction towards the substrate, e.g. through an outlet or a nozzle. A crucible may be understood as a device or a reservoir providing or containing the material to be deposited. Typically, the crucible may be heated for evaporating the material to be deposited on the substrate. The crucible may stand in fluid communication with a distribution pipe, to which the material being evaporated by the crucible may be delivered.

[0016] According to some embodiments described herein, a distribution pipe may be understood as a pipe for guiding and distributing the evaporated material. In particular, the distribution pipe may guide the evaporated material from an evaporator to an outlet (such as nozzles or openings) in the distribution pipe. A linear distribution pipe may be understood as a pipe extending in a first, especially longitudinal, direction. In some embodiments, the linear distribution pipe includes a pipe having the shape of a cylinder, wherein the cylinder may have a circular bottom shape or any other suitable bottom shape. Examples of distribution pipes will be described in detail below.

[0017] A nozzle as referred to herein may be understood as a device for guiding a fluid, especially for controlling the direction or characteristics of a fluid (such as the rate of flow, speed, shape, and/or the pressure of the fluid that emerges from the nozzle). According to some embodiments described herein, a nozzle may be a device for guiding or directing a vapor, such as a vapor of an evaporated material to be deposited on a substrate. The nozzle may have an inlet for receiving a fluid, a passage (e.g. a bore or opening) for guiding the fluid through the nozzle, and an outlet for releasing the fluid. Typically, the passage may include a passage wall surrounding a passage channel, through which the evaporated material may flow. According to embodiments described herein, the passage of the nozzle may include a

defined geometry for providing the fluid flowing through the nozzle with a predetermined direction or characteristic. According to some embodiments, a nozzle may be part of a distribution pipe or may be connectable or connected to a distribution pipe providing evaporated material and may receive evaporated material from the distribution pipe.

[0018] According to embodiments described herein, a nozzle for being connected to a distribution pipe is provided. In some embodiments, the nozzle may exchangeably be connectable to a distribution pipe such as by providing a thread. Typically, the nozzle is configured for guiding evaporated material from a material source into a vacuum chamber. The nozzle includes a nozzle inlet for receiving the evaporated material (e.g. from a distribution pipe), a nozzle outlet for releasing the evaporated material to the vacuum chamber, and a nozzle passage between the nozzle inlet and the nozzle outlet along a length direction of the nozzle. The nozzle passage has a passage wall surrounding a passage channel (which may be understood as the hollow part of the nozzle).The nozzle further includes at least two fins extending into the passage channel.

[0019] Figs. 1a to 1c show examples of nozzles according to embodiments described herein. All examples of nozzles 400 show a nozzle inlet 401, a nozzle outlet 403, and a passage 402 between the nozzle inlet 401 and the nozzle outlet 403. According to some embodiments, the evaporated material coming from the material source (such as a crucible) is guided into a distribution pipe and enters the nozzle through the nozzle inlet 401. The evaporated material then passes through the nozzle passage 402 and exits the nozzle at the nozzle outlet 403. The flow direction of the evaporated material can be described as running from the nozzle inlet 401 to the nozzle outlet 403. The nozzle 400 further provides a length direction 460 running along the length of the nozzle.

[0020] According to embodiments described herein, the nozzle passage 402 includes a passage wall 404 surrounding a passage channel 405 (shown in Fig. 1b only for the sake of a better overview). The passage wall 404 surrounding the passage channel 405 may be understood in that the walls surround the channel at least partially, e.g. surround the channel over the circumference of the channel. The passage wall leaves the channel open at two ends, i.e. the nozzle inlet and the nozzle outlet. According to embodiments described herein, the nozzle includes at least two fins 406 extending into the passage channel 405 of the nozzle.

[0021] A "fin" as used herein may be understood as an element providing a surface, which offers a possibility for particles to bounce off. For instance, the fin may be formed so as to offer a surface being oriented in direction of a beneficial main flow in the nozzle (such as a flow along the length direction of the nozzle). In one example, the fin may be understood as an element having a surface allowing the particles to bounce off in a direction substantially parallel to the length direction of the nozzle, or within an angular range of 20° to 30° around the length direction of the nozzle. The surface of the fin may provide an angle of about 75° to about 105° to the length direction of the nozzle. According to some embodiments, the fin may offer a surface (e.g. a surface facing the nozzle outlet) being substantially perpendicular to the length direction of the nozzle.

[0022] In some examples, the fins may typically extend from the passage wall in a fin extension plane having an angle of about 75° to about 105° relative to the length direction of the nozzle, more typically in an angle of about 80° to about 100°, and even more typically in an angle of about 90°. The fin extension plane may be defined as a plane containing the center point and the tip of a fin (as will be shown in Figs. 5a to 5f). According to some embodiments, the fin extension plane may be understood as including a surface of the fin (such as surface 503 of Fig. 5c). In some embodiments, the surfaces of the fins facing the outlet of the nozzle may provide an angle of substantially 90° to the length direction of the nozzle. Details of the fin geometry will be explained below, also referring to the surfaces of the fins facing the nozzle outlet.

[0023] As can be seen in Fig. 1c, the fins 406 may be provided by a ring-like structure around the circumference of the nozzle. The skilled person may understand that the fins are not limited to a ring-like structure, but may also provide single fins extending into the passage channel, or an interrupted ring-like structure. Further, the fins may be adapted to the shape of the passage channel of the nozzle. For instance, if the passage channel has a shape (seen perpendicular to the length direction of the nozzle) deviating from the circular shape (such as an elliptical shape, a long-hole shape, a substantially rectangular shape, a substantially quadratic shape, a triangular shape, or any suitable shape for guiding evaporated material through the nozzle), the fins may provide a structure following or resembling the shape of the nozzle.

[0024] The term "substantially" as used herein may mean that there may be a certain deviation from the characteristic denoted with "substantially." Typically, a deviation of about 15% of the dimensions or the shape of the characteristic denoted with "substantially" may be possible. For instance, the term "substantially circular" refers to a shape which may have certain deviations from the exact circular shape, such as a deviation of about 1 to 15% or 10% of the extension in one direction, if suitable. In some embodiments, a value may be described with "substantially." The skilled person may understand that the value described with "substantially" may have a deviation of about 1% to about 10% or 15% from the named value. For instance, "substantially perpendicular" may include an angle of 75° to 105°.

[0025] According to some embodiments described herein, the number of fins in the nozzle may be at least two. However, the nozzle may include more than two fins, typically more than 10 fins, more typically more than 15 fins, and even more typically more than 20 fins. In some embodiments, the whole length of one nozzle stage may be equipped with fins. For instance, the fins may be provided at a distance of typically less than 2 mm from each other, more typically less than 1.5 mm from each other and even more typically less than 1 mm from each other. In one example, the distance between the fins in the nozzle length direction is about 0.7 mm.

[0026] The nozzle design with fins according to embodiments described herein is able to improve the focus of the material flow of an evaporated material to the substrate. The nozzle described herein may be used to focus evaporated material in the gaseous phase from an evaporator source to a substrate within a vacuum chamber, e.g. for generating an OLED active layer on a substrate. In some embodiments, the nozzle is adapted for a mass flow of less than 1 sccm. For instance, the mass flow within a nozzle according to embodiments described herein may typically be only a fractional amount of 1 sccm, and 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.

[0027] As shortly described above, the design of the nozzle includes fins, or at least a stage with fins or ring structures, which have a surface orientation in the direction of the flow (i.e. the surface of the fins is oriented in a direction from nozzle inlet to nozzle outlet) compared to other tube stages, which have a surface orientation of the walls perpendicular to the flow direction. Especially at low pressure in the molecular or molecular/transient pressure regime,

a surface orientation in flow direction as described in embodiments described herein will focus more wall diffuse reflected (desorbed) particles in a beneficial direction of the flow with a smaller degree of deviation from the ideal center line of flow. According to some embodiments, the ideal line of article flow, or the beneficial flow direction, may be a direction being substantially parallel to the nozzle length direction.

[0028] Typically, particles of evaporated material enter the nozzle at the nozzle inlet with a beneficial flow direction (main flow direction) in the direction of the nozzle length direction. However, due to particle-particle interaction, bouncing effects of the passage walls and incomplete directionality of the flow of particles entering the nozzle, several particles spread from a beneficial flow direction. The spread particles may come into contact with the passage walls, or in embodiments described herein, with the fins at the passage wall. The particles in a nozzle according to embodiments described herein, which come into contact with the fins are re-bounced by the surface of the fin facing the nozzle outlet (or, are re-bounced at least from the tip of the fin being the point of the fin closest to the center line in length direction of the nozzle passage). Due to the orientation of the fin surface in flow direction, the particles are re-bounced in a substantially straight direction, e.g. substantially parallel to the length direction of the nozzle, and join the main fluid flow again, especially within a defined angle range. In one example, the substantially parallel direction may include a deviation from the exact parallel direction to the length direction of the nozzle of about 10° to about 30°. Some particles may not hit the fins at the tip of the fins rather closer to the passage wall so that the particles cannot be re-joined to the main fluid flow, but will be bounced between the fins until the particles reach the tip. Particles having a deviation from the beneficial flow direction (such as parallel to the nozzle length direction) will be re-directed by the fins according to embodiments described herein. In a nozzle according to embodiments described herein, particles, which would spread the angle of the evaporated material flow in another nozzle, are now re-directed and help to densify the flow of evaporated particles to a beneficial hitting spot on the substrate.

[0029] The figures showing examples of embodiments described herein further show nozzles with passages having stages of different sizes. For instance, Fig. 1a shows a nozzle 400 with a first stage 410 and a second stage 420. The first stage 410 of the nozzle 400 provides a first stage size 411 and a first stage length 412. The second stage 420 of the nozzle 400 provides a second stage size 421 and a second stage length 422. According to

embodiments described herein, the second stage size may typically be between 2 to 10 times larger than the first stage size, more typically between 2 and 8 times larger, and even more typically between 3 and 7 times larger. In one example, the second stage size may be 4 times larger than the first stage size.

[0030] According to some embodiments described herein, a stage size of a nozzle may be understood as the size of a stage of the nozzle passage (or opening). In one embodiment, the stage size may be understood as being one dimension of the stage, which is not the stage length. According to some embodiments, the stage size may be the minimum dimension of the cross-section of the nozzle stage. For example, a circular shaped nozzle stage may have a size being the diameter of the stage. According to some embodiments described herein, the stage length of a stage of a nozzle may be understood as the dimension of the stage along the length direction of the nozzle, or along the main flow direction of the evaporated material in the nozzle.

[0031] In some embodiments, which may be combined with other embodiments described herein, the first stage of a nozzle may include the nozzle inlet. In some embodiments, which may be combined with other embodiments described herein, the second stage of a nozzle may include the nozzle outlet. According to some embodiments, the size of the first stage may typically be between 1.5 mm and about 8 mm, more typically between about 2 mm and about 6 mm, and even more typically between about 2 mm and about 4 mm. According to some embodiments, the size of the second stage may be between 3 mm and about 20 mm, more typically between about 4 mm and about 15 mm, and even more typically between about 4 mm and about 10 mm. According to some embodiments, which may be combined with other embodiments described herein, the length of a nozzle stage as described herein may typically 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. In one example, the length of one of the nozzle stages may be about 5 mm to about 10 mm.

[0032] According to some embodiments, the effect of the fins (such as decreasing the area of the spot at which the particles hit the substrate) may be emphasized with differently sized stages within the nozzle. According to embodiments described herein, the second stage (being typically arranged adjacent to the first stage) may be configured for increasing the directionality of the evaporated material. For instance, the evaporated material flowing from

the first stage to the second stage will spread when leaving the first stage which has a smaller size than the second stage. The second stage, however, may catch the evaporated material spreading from the first stage 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 other systems, the plume is more precisely directed towards the substrate, or towards a mask (e.g. a pixel mask), as will be explained in detail below with respect to Figs. 6a, 6b and 7.

[0033] However, the skilled person may understand that the fins as described in embodiments herein may also be used in nozzles without differently sized stages.

[0034] Fig. 2 shows an embodiment of a nozzle having three stages and fins in one of the stages. The nozzle 400 of Fig. 2 includes a first stage 410 having a first stage size 411, a second stage 420 having a second stage size 421, and a third stage 430 having a third stage size 431. In the embodiment shown in Fig. 2, the third stage size 431 is larger than the second stage size 421, and the second stage size 421 is larger than the first stage size 411. For instance, the ratio between the third stage size 431 and second stage size 421 and/or the ratio between second stage size and first stage size may typically be between about 1.5 to about 10, more typically between about 1.5 and 8, and even more typically between about 2 and 6.

[0035] In the embodiment shown in Fig. 2, the third stage 430 includes the nozzle outlet 403. As shown in the example of Fig. 2, the first stage 410 includes the nozzle inlet. According to some embodiments, the first stage 410 may be denoted as first expansion stage, the second stage 420 may be denoted as second expansion stage and the third stage may be denoted as third expansion stage. The nozzle 400 includes fins 406 in the second expansion stage 420. In some embodiments, the part of the nozzle including fins may be denoted as molecular focus part of the respective stage.

[0036] According to some embodiments, the fins 406 encompass a size 461, which e.g. is the minimum dimension of the cross-section in a direction perpendicular to the length direction of the nozzle. The size encompassed by the fins may be described as the space between two opposing fins measured in a direction being substantially perpendicular to the length direction 460 of the nozzle. In some embodiments, the size 461 encompassed by the fins 406 may be larger than the size of the stage preceding the stage with the fins. For

instance, as can be seen in Fig. 2, the size 461 encompassed by the fins 406 is larger than the first stage size 411. In the example shown in Fig. 2, the size 461 encompassed by the fins 406 is smaller than the second section size 421 and smaller than the third section size 431.

[0037] According to some embodiments, the nozzle according to embodiments described herein is not limited to two or three stages as shown in the figures. Generally, a nozzle according to embodiments described herein may include further stages, such as n stages being adjacently arranged. Typically, each of the n stages may provide a larger size than the preceding stage, when going in a direction from the nozzle inlet to the nozzle outlet. In one example, n is typically larger than 2, more typically larger than 3. At least one of the stages of the n stages may include fins extending into the passage channel of the nozzle. According to some embodiments, the stage having the largest size of all nozzle stages may contain the fins. In one example, the stage providing the lowest pressure of all nozzle stages may contain the fins.

[0038] According to some embodiments described herein, the nozzle (in particular the different nozzle stages) may provide an increasing conductance value with increasing distance to the nozzle inlet. For instance, each stage may provide at least one conductance value, wherein the conductance value is larger the nearer the stage is to the nozzle outlet. As an example (and not limited to the particular embodiment), the second stage 420 of Fig. 2 may have a higher conductance value than the first stage 410, wherein the first stage precedes the second stage in a direction from the nozzle inlet to the nozzle outlet. According to some embodiments, each stage provides a lower pressure level (than the preceding stage when looked at in the direction from the nozzle inlet to the nozzle outlet) with decreasing distance of the stage to the nozzle outlet. According to some embodiments, the conductance value may be measured in l/s. In one example, the flow within the nozzle being below 1 sccm may also be described as being below 1/60 mbar l/s. In some embodiments, the stage size may be chosen so as to provide an increasing conductance value of each stage with decreasing distance to the nozzle outlet. According to some embodiments described herein, a stage may provide a typically larger or substantially equal conductance value than the preceding stage in a direction from the nozzle inlet to the nozzle outlet.

[0039] According to some embodiments described herein, the stage(s) being located nearer to the nozzle outlet (or stages including the nozzle outlet) may have a larger stage size than

the stage(s) being located nearer to the nozzle inlet (or stages including the nozzle inlet). For instance, a center point of the nozzle in the longitudinal direction of the nozzle (shown as axis 460 in Fig. 1a and 2) may be a reference for the stage located nearer to the nozzle inlet or the nozzle outlet.

[0040] Fig. 3 shows an embodiment of a nozzle including three stages, namely a first stage 410, a second stage 420, and a third stage 430. Fins 406 extend into the passage channel and are located between the second stage 420 and the third stage 430 or within the third stage. As can be seen in the example of Fig. 3, the size encompassed by the fins 406 corresponds approximately to the size 421 of the second stage 420. However, Fig. 2 shows an embodiment, where the fins encompass a size larger than the size of the stage preceding the stage with fins. For instance, in Fig. 2the size 461 encompassed by the fins 406 have a larger size than the stage 410, which is the stage preceding stage being stage 410 in Fig. 2. The size encompassed by the fins being larger than the preceding stage size may have a better impact on the effect of the fins in the nozzle. In some embodiments, the part of the nozzle including the fins 406 may also be denoted as the molecular focus part of the second expansion stage 420.

[0041] According to some embodiments, the first stage 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 stage, or by generally having a smaller size when compared to the diameter of the distribution pipe. According to some embodiments, the diameter of the distribution pipe (to which the nozzle may be connected, or of which the nozzle may be part) may typically be between about 70 mm and about 120 mm, more typically between about 80 mm and about 120 mm, and even more typically between about 90 mm and about 100 mm. In some embodiments described herein (e.g. in the case of a distribution pipe having a substantially triangular like shape as explained in detail below with respect to Figs. 10a and 10b), the above described values for the diameter may refer to the hydraulic diameter of the distribution pipe. According to some embodiments, the comparatively narrow first stage may force the particles of the evaporated material to arrange in a more uniform manner. Making the evaporated material more uniform in the first stage 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. A more uniform

flow results in less spreading particles and a smaller spreading angle. The stages present in the nozzle may further improve the effect achieved by the fins.

[0042] The skilled person may understand that in a material deposition arrangement according to embodiments described herein, such as a material deposition arrangement for evaporating organic materials, the evaporated material flowing in the distribution pipe and the nozzle (or parts of the nozzle) may be considered as a Knudsen flow. In particular, the evaporated material may be considered as a Knudsen flow in view of the flow and pressure conditions in the distribution pipe and the nozzle for guiding evaporated material in a vacuum chamber, which will be explained in detail below. According to some embodiments described herein, the flow in a portion of the nozzle (such as a portion being close to or adjacent to the nozzle outlet or including the nozzle outlet) may be a molecular flow. For instance, the second stage of the nozzle according to embodiments described herein may provide a transition between a Knudsen flow and a molecular flow. In one example, the flow within the vacuum chamber, but outside of the nozzle, may be a molecular flow. According to some embodiments, the flow in the distribution pipe may be considered as being a viscous flow or a Knudsen flow. In some embodiments, the nozzle may be described as providing a transition from the Knudsen flow or viscous flow to the molecular flow.

[0043] The skilled person may understand that the last stage before the nozzle outlet or the stage including the nozzle outlet may provide the lowest pressure within the nozzle. As described above, a stage being located near to the nozzle outlet (or including the nozzle outlet) may provide a molecular flow or a flow close to the molecular flow regime of the evaporated material. According to some embodiments, the fins in the nozzle may be located in the stage having the lowest pressure within the nozzle and/or in a stage providing a molecular flow or a flow close to the molecular flow regime. For instance, the fins may typically be provided in the last stage of the nozzle before the nozzle outlet and/or the stage of the nozzle including the nozzle outlet (e.g. stage 430 in Fig. 3 or stage 420 in Fig. 1b).

[0044] Further features may be added to a nozzle according to embodiments described herein, so as to even further increase the effect of a more focused deposition on the substrate. For instance, as can be seen in the embodiment of Fig. 1b, the nozzle 400 may include a fringe stage 440 (typically located at the nozzle outlet 403). According to some embodiments, the fringe stage 440 may have different fringe stage sizes along the length direction of the

nozzle. For instance, the fringe stage size may be smaller at a first end of the fringe stage 440 being adjacent to another stage (e.g. the second stage 420) than at a second end of the fringe stage at the nozzle outlet 403. In the schematic view of Fig. 1b, the fringe stage 440 provides tapered walls. In one embodiment, the shape of the fringe stage 440 may be described as being funnel like or cap like. According to some embodiments, the length of the fringe stage 440 may be equal to or smaller than the length of the first and/or the second stage. In one example, the length of the fringe stage may typically be between 1/6 and 2/3 of the first and/or second stage length.

[0045] The skilled person may understand that other embodiments of the nozzle for a material deposition arrangement according to embodiments described herein may be equipped with a fringe stage as exemplarily shown in Fig. 1b.

[0046] In a further example, a further or last stage may be applied, which can be total absorbent, partial absorbent or non-absorbent. Fig. 4a shows an example of a nozzle 400, which may be a nozzle as described before in Figs. 1 to 3. At the nozzle outlet, an absorber stage 470 is provided. The absorber aperture 470 may be provided in front of the nozzle outlet between the nozzle outlet and the substrate or the mask. In some embodiments, the absorber stage may have a substantially circular or cylindrical shape and provides an opening 471 for the evaporated material exiting the nozzle through the nozzle outlet. According to some embodiments, the absorber stage or the opening of the absorber stage may be configured so that the majority of material with a spreading angle of larger than 30° degree is absorbed at the walls of the absorber stage. The resulting material distribution on the substrate is even more improved with a bright focus within +/- 20 degree, or at least +/- 30 degree.

[0047] In one example, which may be combined with other embodiments described herein, the opening 471 of the absorber stage 470 may have a larger size than the nozzle outlet. In one example (and depending on the size of the nozzle outlet), the opening 471 of the absorber stage is typically between about 15 mm and about 30 mm, more typically between about 15 mm and about 25 mm, and even more typically about 20 mm. According to some embodiments, more than one nozzle is provided in a row so that the distance between the nozzle (being e.g. 20 mm) may be considered when defining the size of the absorber stage. The length of the absorber stage (e.g. measured in the nozzle length direction) may typically

be between about 25 mm and about 50 mm, more typically between about 30 mm and about 45 mm, and even more typically between about 30 mm and about 40 mm.

[0048] According to some embodiments, the absorber stage 470 may be attached to the nozzle 400, e.g. by being in contact with the nozzle, or by a clamping or holding device or the like. Typically, the absorber stage 470 may thermally be decoupled from the nozzle 400 (for instance, the nozzle may be heated and the absorber stage not). In one example, there is no contact or only a loose contact between the nozzle and the absorber stage for avoiding a thermal energy exchange between the nozzle and the absorber stage, which exceed a defined amount. The absorber stage being not heated and at a lower temperature than the nozzle may capture and absorb (or adsorb) the particles spreading in an angle of larger than 30°, in particular due to the condensation of the evaporated material at the walls of the (cooler) absorber stage.

[0049] The absorbent stage may also help reducing the contamination of the chamber, because nearly all particles of the evaporated material land on the substrate or the absorbent stage. In addition, the use of an absorbent stage reduces (and improves) the interaction of a row of several nozzles by avoiding material flows from one nozzle with an angle larger than 30° degrees, which could disturb the flow of neighboring nozzles by hitting the molecules of the neighboring nozzle. The material distribution in direction of the nozzle row on the substrate - especially at the ends of the nozzle row - is improved.

[0050] To reduce the material absorption at the absorber stage, a purge /block gas could be used. An example gas may for instance be Ar. The gas may be chosen so as to not chemically interact with the OLED material e.g. Alq3 and have a relatively high molecular mass to be able to physically act against typically heavy OLED molecules (AMass 400 to 800). The block gas inlet may be provided by many small holes in the cylindrical wall of the absorbent stage. A very effective way could be to build the absorbent stage of a sinter metal (e.g. AMPOR Inox) with thousands of holes and channels and to supply the sinter wall with block gas from outside. The amount of block gas which could be used is limited, because the residual block gas pressure in the process chamber will scatter OLED molecules on their way from nozzle to the substrate. According to some embodiments, a combination of block gas plus accelerated wall temperature may be used to define a partial absorbent stage. According to some embodiments, the absorber stage may also be made from a metal. If the stage is at or

above OLED material condensation temperature like the rest of the nozzle, the stage is non-absorbent. For an adsorbent or partial adsorbent nozzle stage a quick exchange of the adsorbent surface or absorber stage together with the adsorbed material enables a mostly continuous operation of the evaporator system. The quick exchange may for instance be realized by e.g. removable inserts or a row of connected mainly cylindrical parts which could be exchanged at once as a separate part. The cleaning of the removed inserts may be done in a separate chamber, e.g. in a chamber for source preparation or source stand by.

[0051] In one example, the nozzle may additionally or alternatively be equipped with an absorber aperture 470, as exemplarily shown in Fig. 4b. The absorber aperture 470 may be provided in front of the nozzle outlet between the nozzle outlet and the substrate or the mask. The absorber aperture 470 may include an opening 471, or several openings in the case that one absorber aperture is used for a plurality of adjacently arranged nozzles. In some embodiments, if a plurality of openings is provided for a plurality of adjacently arranged nozzles, a partitioning wall may be provided for separating the openings of the aperture plate for the single nozzles in order to avoid an interaction of the spreading material of adjacent nozzles. According to some embodiments, the absorber aperture or the opening of the absorber aperture may be configured so that the majority of material with a spreading angle of larger than 30° degree is absorbed at the walls of the screen of the absorber aperture. The resulting material distribution on the substrate is even more improved with a bright focus within +/- 20 degree, or at least +/- 30 degree.

[0052] Figs. 5a to 5f refer to the shape of the fins in the nozzle. Fig. 5a shows a nozzle 400 according to embodiments described herein. The nozzle 400 includes a nozzle passage 402 having a passage wall 404 surrounding a passage channel 405. Fins 406 extend from the passage wall 404 into the passage channel 405, typically in the direction of the center axis or length direction 460 of the nozzle 400. Figs. 5b to 5f refer to the detail 480 as indicated in Fig. 5a showing three fins of the nozzle and a part of the passage wall.

[0053] Figs. 5b to 5f show different embodiment, which may be combined with other embodiments described herein. In particular, the embodiments shown in Figs. 5b to 5f are not limited to the nozzle design shown in Fig. 5a. Figs. 5b to 5f show a cross-section of the fins cut in a plane containing the length direction of the nozzle. According to some embodiments, the fins as described herein may be integrally formed with the passage wall, may be after-

treated after being integrally formed, may partially integrally be formed with the passage wall or may be formed as an extra part and then fixed to the passage wall. For instance, the fins may be cut into the chamber walls (such as a thread), milled into the chamber walls, by turning, or may be fixed to the chamber walls by an adhesive, a fixation means or the like.

[0054] Fig. 5b shows an example, where the fins have a substantially rectangular cross section, in particular when cut in the plane of the length direction of the nozzle. The fin 406 has a fin tip 501 or fin tip region being the position of the fin close to the length axis 460 of the nozzle, a fin end 502 or fin end region being the position close to the passage wall 404, a top surface 503 being the surface of the fin facing the nozzle outlet and a bottom surface 504 being a surface facing the nozzle inlet. In the embodiment shown in Fig. 5b, the top surface 503 as well as the bottom surface 504 are oriented substantially perpendicular to the length direction of the nozzle. The top surface 503 and the bottom surface 504 are oriented in the flow direction. Particles hitting e.g. the top surface 503 are directed in a beneficial flow direction running substantially parallel to the length direction 460 of the nozzle. In particular, as also explained above, particles hitting the fins in the region of the tip 501 are directed into the main flow of particles in the passage channel 405. Particles, which hit the fins in a region behind the tip 501 may be re-bounced by the adjacent fin until the particles reach the tip region 501 of the fin for not introducing a spreading angle into the main flow.

[0055] Fig. 5c shows an example for fins 406, where the fins 406 have a substantially triangular cross-section, when cutting the fin in a plane of the length direction 460 of the nozzle. In the embodiment shown in Fig. 5c, the triangular cross-section is formed so that the top surface 503 of the fin facing the nozzle outlet is substantially perpendicularly arranged to the length direction 460 of the nozzle. For instance, the top surface 503 is typically arranged at an angle of about 75° to about 105°, more typically at an angle of about 80° to about 100°, and even more typically between about 85° and about 95° to the length direction 460 of the nozzle. In one example, the top surface of the fin is arranged at an angle of about 90° to the length direction 460 of the nozzle. The bottom surface 504 is tapered with respect to the top surface 503, and the tip region 501 has a smaller extension in the length direction 460 of the nozzle than the end region 502. According to some embodiments, the shape shown in Fig. 5c may be formed by cutting a thread into the passage wall 404 of the nozzle and subsequent treatment of the top surface. The shape shown in Fig. 5c may be denoted as lamella-like shape in some embodiments.

[0056] Fig. 5d shows an example of the fins 406, where the fins have a triangular shape of the cross-section, when cutting the fin 406 in a plane of the length direction 460 of the nozzle. In the embodiment shown in Fig. 5d, the top surface 503 and the bottom surface 504 of the fins are tapered with respect to the perpendicular direction to the length direction 460 of the nozzle. The top surface is not completely oriented in the beneficial flow direction of the particles in the passage channel 405. However, particles hitting the tip 501 of the fins may still be re-bounced into a beneficial direction range (e.g. with an angle of less than 30° or less than 20° from the beneficial flow direction). Further, the re-bouncing angle depends on the angle of the fin surfaces so that a relatively flat angle of the surfaces (e.g. an angle of about 5° to about 25°) may still have the effect of re-directing spread particles. According to some embodiments, the triangular shaped fins may be formed by cutting a thread into the passage wall 404.

[0057] Fig. 5e shows an example, where the triangular shape of the cross-section of the fins is extended with a flat tip 501. For instance, the fins with the cross-section shown in Fig. 5e may be formed by cutting a thread into the wall 404 and subsequent treatment of the tip 501 of the fin. Particles impinging from the fin tip 501 may be directed into the beneficial flow direction in length direction 460 of the nozzle.

[0058] Fig. 5f shows an example of a fin having a triangular cross-section, where the top surface 503 and the tip 501 are substantially perpendicular to the length direction 460 of the nozzle. The shown example may for instance be formed by providing the bottom surface 504 of the fin 406 and subsequent fixing of the top surface 503 (having a chosen length) to the bottom surface. The skilled person may understand that the shape of the fins is not limited to the examples shown in Figs. 5b to 5f and that the fins may have any suitable shape (including round or oval shapes or the like).

[0059] According to some embodiments, which may be combined with other embodiments described herein, the size encompassed by the fins (i.e. the size between one fin tip to an opposing fin tip, or the opening provided by a fins in the fin extension plane) may be between the first section size and the second section size, or may be equal to the second section size. In one embodiment, the size encompassed by the fins may be larger than the section size of the section preceding the section including the fins. In some embodiments, the size encompassed by the fins may typically be between about 2 mm and about 20 mm, more typically between

about 3 mm and about 15 mm, and even more typically between about 4 mm and about 10 mm. In one example, the size encompassed by the fins may be about 5 mm. In some embodiments, the width of the fins from the fin tip 501 to the fin end 502 may typically be between about 0.5 mm to about 4 mm, more typically between about 1 mm and about 3 mm, and even more typically, between 1 mm and about 2.5 mm. In one example, the width of the fins from fin tip 501 to the fin end 502 may be about 1.5 mm.

[0060] According to some embodiments, the nozzle together with the fins may be heated, e.g. in order to avoid condensation of the evaporated material in the nozzle. For instance, the nozzle (or parts of the nozzle, or the distribution pipe, to which the nozzle is connected) may be held at a temperature, which is typically about 1°C to about 30°C, more typically about 5°C to about 25°C, and even more typically about 10°C to about 15°C higher than the evaporation temperature of the material to be deposited on the substrate. In some embodiments, the fins may be heated separately from the nozzle. In some embodiments, the nozzle may include a heating device for heating the fins and/or the nozzle passage wall.

[0061] Going to Figs. 6a and 6b, the effect of the nozzle in a material source arrangement according to embodiments described herein can be seen and compared to another nozzle (e.g. without fins) in a material source system. In Fig. 6a, test data of the distribution of evaporated material as released from a nozzle in a material source arrangement according to embodiments described herein is shown. The curve 800 shows a schematic view of the experimental result of an evaporated material released from a nozzle having fins in the passage channel and a first stage and a second stage as described above. The example of Fig. 6a shows that the distribution of evaporated material follows approximately a $\cos^{10}$ like shape. According to some embodiments, the material distribution of the material deposition arrangement may have a shape corresponding approximately to a $\cos^{12}$ like shape or even $\cos^{14}$ like shape. In detail, the distribution of the evaporated material released from a nozzle of a material deposition arrangement according to embodiments described herein may correspond to the above named cos-shapes only with regard to an upper part. For instance, the shown curve does not cross the zero line as a cosinus curve would do. The curve may be described as following the Clausing formula.

[0062] The comparison with another material deposition arrangement as shown in Fig. 6b shows that the distribution of conventional material deposition arrangements corresponds to a

$\cos^1$ shape as shown by curve 801. According to some embodiments, the curve of a nozzle of another deposition system may also achieve $\cos^5$ or $\cos^6$ like shapes. The difference between the curve 800 generated by a nozzle in a material source arrangement according to embodiments described herein and the curve 801 of other systems is substantially the width of the plume of evaporated material and the concentration distribution of the evaporated material in the plume. For example, if masks are used for depositing material on a substrate, such as in an OLED production system, the mask may be a pixel mask with pixel openings having the size of about 50 μm x 50 μm, or even below, such as a pixel opening with a dimension of the cross section (e.g. the minimum dimension of a cross section) of about 30 μm or less, or about 20 μm. In one example, the pixel mask may have a thickness of about 40 μm. Considering the thickness of the mask and the size of the pixel openings, a shadowing effect may appear, where the walls of the pixel openings in the mask shadow the pixel opening. The nozzle having fins according to embodiments described herein may help in reducing the shadowing effect.

[0063] Gas flow simulations of the material deposition arrangement according to embodiments described herein show that the herein described nozzle design is able to concentrate material deposition on a substrate on a small area of +/- 30 degree (or +/-20 degree) (looking from the nozzle in the direction of the material (gas) flow to the substrate). In the special case of the deposition of e.g. Alq3 for OLED manufacturing, the small area may be considered as one factor to form a high pixel density (dpi) on a display.

[0064] The high directionality, which can be achieved by using the evaporation with a nozzle in a material source arrangement according to embodiments described herein, further leads to an improved utilization of the evaporated material, because more of the evaporated material actually reaches the substrate (and, for instance, not the area above and below the substrate).

[0065] Fig. 7 shows a schematic diagram of the material distribution of a nozzle according to embodiments described herein compared to another nozzle. Fig. 7 shows a substrate 121 being subjected to a flow of evaporated material coming from a nozzle. The material flow marks deposition spots on the substrate, such as deposition spots 802 and 804. The deposition spots 802 and 804 indicate the material hitting the substrate, and providing the coating on the substrate. Deposition spot 804 is provided by another nozzle without fins, while deposition

spot 802 is provided by a nozzle according to embodiments described herein. The material source is exemplarily denoted with 806 and is firstly operated with another nozzle without fins for obtaining the deposition spot 804 and then operated with a nozzle according to embodiments described herein for obtaining deposition spot 802. As can be seen in Fig. 7, the angle 807 encompassed by the deposition spot 804 is larger than the angle 808 encompassed by the deposition spot 802. For instance, the angle 808 may typically be less than 30°, more typically less than 25° and even more typically about 20°. The angle 807 of the other system may be about 40° or more. Fig. 7 does not only show the smaller angle of the deposition spot achieved with a nozzle according to embodiments described herein, but also the higher material density in the center of the deposition spots 804 and 802, respectively. The darker the color, the higher the density of the deposition spot. The center 803 as well as the surroundings of the deposition spot 802 is darker than the center 805 and the surroundings of the deposition spot 804. According to some embodiments, the smaller angular size of the deposition spot 802 results in a higher material density, when the deposition rate is the same. Experimental results of a material source arrangement having a nozzle according to embodiments described herein show 35% to 40% more material in the center of the deposition spot and less material at the +/- 20° and +/-30° limit lines than other systems. The improvement compared to other systems is very effectual and could not be achieved by design changes as usually done in a simple cylindrical nozzle. A smaller sport size and a higher density (especially within the 20°-30° angle range) allows, as described above, using smaller pixel masks, avoiding shadowing effects of the masks and improves the accuracy and the quality of the end product.

[0066] According to some embodiments, a material source arrangement for depositing a material on a substrate in a vacuum deposition chamber is described. The material source arrangement typically includes a distribution pipe configured to be in fluid communication with a material source (e.g. an evaporator or a crucible) providing the material to the distribution pipe. The material source arrangement further includes at least one nozzle according to embodiments described above, e.g. with respect to Figs. 1 to 5.

[0067] Fig. 8 shows an example of a material source arrangement 100 according to embodiments described herein. The material source arrangement includes two evaporators 102a and 102b, and two distribution pipes 106a and 106b standing in fluid communication with the evaporators 102a and 102b.

[0068] The material deposition arrangement further includes nozzles 712 in the distribution pipes 106a and 106b. The nozzles 712 may be nozzles as described above with respect to Figs. 1 to 5. The nozzles 712 of the first distribution pipes have a longitudinal direction 211, which may correspond to the axis 460 of the nozzle 400 exemplarily shown in Fig. 1a. According to some embodiments, the nozzles 712 may have a distance between each other. In some embodiments, the distance between the nozzles 712 may be measured as the distance between the longitudinal directions 211 of the nozzles. According to some embodiments, which may be combined with other embodiments described herein, the distance between the nozzles may typically be between about 10 mm and about 50 mm, more typically between about 10 mm and about 40 mm, and even more typically between about 10 mm and about 30 mm. According to some embodiments described herein, the above described distances between the nozzles may be useful for the deposition of organic materials through a pixel mask, such as a mask having an opening size of 50 μm x 50 μm, or even less, such as a pixel opening with a dimension of the cross section (e.g. the minimum dimension of a cross section) of about 30 μm or less, or about 20 μm. In some embodiments, the second stage size of the nozzles may be chosen dependent on the distance between the nozzles. For instance, if the distance between the nozzles is 20 mm, the second stage size of the nozzle (or the stage size of a stage including the nozzle outlet, or the stage having the largest size of the stages in the nozzle) may be up to 15 mm, or less. According to some embodiments, the distance between the nozzles may be used for determining the ratio of the second stage size to the first stage size.

[0069] According to some embodiments, a vacuum deposition system is provided. The vacuum deposition system includes a vacuum chamber and a material source arrangement as exemplarily described above in embodiments. The vacuum deposition system further includes a substrate support for supporting the substrate during deposition. In the following, an example of a vacuum deposition system according to embodiments described herein is described.

[0070] Fig. 9 shows a vacuum deposition system 300 in which a nozzle and a material source arrangement according to embodiments described herein may be used. The deposition system 300 includes a material source arrangement (or material deposition arrangement) 100 in a position in a vacuum chamber 110. According to some embodiments, which can be combined with other embodiments described herein, the material source arrangement is

configured for a translational movement and a rotation around an axis. The material deposition arrangement 100 has one or more evaporation crucibles 104 and one or more distribution pipes 106. Two evaporation crucibles and two distribution pipes are shown in Fig. 9. Two substrates 121 are provided in the vacuum chamber 110. Typically, a mask 132 for masking of the layer deposition on the substrate can be provided between the substrate and the material deposition arrangement 100. Organic material is evaporated from the distribution pipes 106. According to some embodiments, the material deposition arrangement may include a nozzle as shown in Figs. 1 to 5. In one example, the pressure in the distribution pipe may be between about 10^{-2}mbar to about 10^{-5}mbar, or between about 10^{-2} to about 10-^{3} mbar. According to some embodiments, the vacuum chamber may provide a pressure of about 10^{-5} to about 10^{-7}mbar.

[0071] According to embodiments described herein, the substrates are coated with organic material in an essentially vertical position. The view shown in Fig. 9 is a top view of a system including the material deposition arrangement 100. Typically, the distribution pipe is a vapor distribution showerhead, particularly a linear vapor distribution showerhead. The distribution pipe provides a line source extending essentially vertically. According to embodiments described herein, which can be combined with other embodiments described herein, essentially vertically is understood particularly when referring to the substrate orientation, to allow for a deviation from the vertical direction of 20° or below, e.g. of 10° or below. The deviation can be provided for example 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. The surface of the substrates is typically 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. According to other embodiments, the deposition system may be a deposition system for depositing material on an essentially horizontally oriented substrate. For instance, coating of a substrate in a deposition system may be performed in an up or down direction.

[0072] Fig. 9 illustrates an embodiment of a deposition system 300 for depositing organic material in a vacuum chamber 110. The material deposition arrangement 100 is movable within the vacuum chamber 110, such as by a rotational or a translational movement. The

material source shown in the example of Fig. 9 is arranged on a track, e.g. a looped track or linear guide 320. The track or the linear guide 320 is configured for the translational movement of the material deposition arrangement 100. According to different embodiments, which can be combined with other embodiments described herein, a drive for the translational or rotational movement can be provided in the material deposition arrangement 100 within the vacuum chamber 110 or a combination thereof. Fig. 9 shows a valve 205, for example a gate valve. The valve 205 allows for a vacuum seal to an adjacent vacuum chamber (not shown in Fig. 9). The valve can be opened for transport of a substrate 121 or a mask 132 into the vacuum chamber 110 or out of the vacuum chamber 110.

[0073] According to some embodiments, which can be combined with other embodiments described herein, a further vacuum chamber, such as maintenance vacuum chamber 210 is provided adjacent to the vacuum chamber 110. Typically, the vacuum chamber 110 and the maintenance vacuum chamber 210 are connected with a valve 207. The valve 207 is configured for opening and closing a vacuum seal between the vacuum chamber 110 and the maintenance vacuum chamber 210. The material deposition arrangement 100 can be transferred to the maintenance vacuum chamber 210 while the valve 207 is in an open state. Thereafter, the valve can be closed to provide a vacuum seal between the vacuum chamber 110 and the maintenance vacuum chamber 210. If the valve 207 is closed, the maintenance vacuum chamber 210 can be vented and opened for maintenance of the material deposition arrangement 100 without breaking the vacuum in the vacuum chamber 110.

[0074] Two substrates 121 are supported on respective transportation tracks within the vacuum chamber 110 in the embodiment shown in Fig. 9. Further, two tracks for providing masks 132 thereon are provided. Coating of the substrates 121 can be masked by respective masks 132. According to typical embodiments, the masks 132, i.e. a first mask 132 corresponding to a first substrate 121 and a second mask 132 corresponding to a second substrate 121, are provided in a mask frame 131 to hold the mask 132 in a predetermined position. The first mask and the second mask may be pixel masks.

[0075] The described material deposition arrangement may be used for various applications, including applications for OLED device manufacturing including processing methods, wherein two or more organic materials are evaporated simultaneously. Accordingly, as for

example shown in Fig. 9, two or more distribution pipes and corresponding evaporation crucibles can be provided next to each other.

[0076] Although the embodiment shown in Fig. 9 provides a deposition system with a movable source, the skilled person may understand that the above described embodiments may also be applied in deposition systems in which the substrate is moved during processing. For instance, the substrates to be coated may be guided and driven along stationary material deposition arrangements.

[0077] Embodiments described herein particularly relate to deposition of organic materials, e.g. for OLED display manufacturing on large area substrates. According to some embodiments, large area substrates or carriers supporting one or more substrates may have a size of at least 0.174 m². For instance, the deposition system may be adapted for processing large area substrates, such as substrates of GEN 5, which corresponds to about 1.4 m^2 substrates (1.1 m x 1.3 m), GEN 7.5, which corresponds to about 4.29 m^2 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 m^2 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. 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 for the substrate, 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 arrangements are adapted for such substrate thicknesses. Typically, the substrate may be made from any material suitable for material deposition. For instance, the substrate may be made from 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.

[0078] According to some embodiment, which may be combined with other embodiments described herein, a material source, an evaporator or a crucible as described herein may be configured to receive organic material to be evaporated and to evaporate the organic material. According to some embodiments, the material to be evaporated may include at least one of ITO, NPD, Alq_3, Quinacridone, Mg/AG, starburst materials, and the like. According to some

embodiments, the nozzle according to embodiments described herein may be configured for guiding evaporated, organic material to the vacuum chamber. For instance, the material of the nozzle may be adapted for evaporated organic material having a temperature of about 100° C to about 600°C. In some embodiments, the nozzle may include a material a thermal conductivity larger than 21 W/mK and/or a material being chemically inert to evaporated organic material. According to some embodiments, the nozzle may include at least one of Cu, Ta, Ti, Nb, DLC, and graphite or may include a coating of the passage wall with one of the named materials.

[0079] According to some embodiments, which may be combined with other embodiments described herein, the distribution pipe of the material source arrangement according to embodiments described herein may have a substantially triangular cross-section. Fig. 10a shows an example of a cross-section of a distribution pipe 106. The distribution pipe 106 has walls 322, 326, and 324, which surround an inner hollow space 710. The wall 322 is provided at an outlet side of the material source, at which a nozzle 712 or several nozzles are provided. The nozzles may be nozzles as described with respect to Figs. 1 to 5. Further, and not limited to the embodiment shown in Fig. 10a, the nozzle may be connectable (such as screwable) to the distribution pipe or may be integrally formed in the distribution pipe. The cross-section of the distribution pipe can be described as being essentially triangular, that is the main stage of the distribution pipe corresponds to a portion of a triangle and/or the cross-section of the distribution pipe can be triangular with rounded corners and/or cut-off corners. As shown in Fig. 10a, for example the corner of the triangle at the outlet side is cut off.

[0080] The width of the outlet side of the distribution pipe, e.g. the dimension of the wall 322 in the cross-section shown in Fig. 10a, is indicated by arrow 352. Further, the other dimensions of the cross-section of the distribution pipe 106 are indicated by arrows 354 and 355. According to embodiments described herein, the width of the outlet side of the distribution pipe is 30% or less of the maximum dimension of the cross-section, e.g. 30% of the larger dimension of the dimensions indicated by arrows 354 and 355. In light of the dimensions and the shape of the distribution pipe, the nozzles 712 of neighboring distribution pipes 106 can be provided at a smaller distance. The smaller distance improves mixing of organic materials, which are evaporated next to each other.

[0081] Fig. 10b shows an embodiment in which two distribution pipes are provided next to each other. Accordingly, a material deposition arrangement having two distribution pipes as shown in Fig. 10b can evaporate two organic materials next to each other. As shown in Fig. 10b, the shape of the cross-section of the distribution pipes 106 allows for placing nozzles of neighboring distribution pipes close to each other. According to some embodiments, which can be combined with other embodiments described herein, a first nozzle of the first distribution pipe and a second nozzle of the second distribution pipe can have a distance of 30 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.

[0082] According to some embodiments, a method for depositing material on a substrate may be provided. A flowchart 500 illustrates a method according to embodiments described herein. With method 500, a material may be deposited on a substrate in a vacuum deposition chamber. According to some embodiments, the vacuum deposition chamber may be a vacuum deposition chamber as described in embodiments above, e.g. with respect to Fig.9. In box 510, the method 500 includes evaporating a material to be deposited in a crucible. For instance, the material to be deposited may be an organic material for forming an OLED device. The crucible may be heated depending on the evaporation temperature of the material. In some examples, the material is heated up to 600°C, such as heated up to a temperature between about 100 °C and 600°C. According to some embodiments, the crucible stands in fluid communication with a distribution pipe. In box 520, the evaporated material is provided to a distribution pipe (e.g. a linear distribution pipe) being in fluid communication with the crucible. In some embodiments, the distribution pipe is at a first pressure level, wherein the first pressure level may for instance be typically between about 10^{-2} mbar to 10^{-5} mbar, more typically between about 10^{-2} mbar and 10^{-3} mbar. According to some embodiments, the vacuum chamber provides a second pressure level, which may for instance be between about 10^{-5} to 10^{-7} mbar.

[0083] In some embodiments, the material deposition arrangement is configured to move the evaporated material using only the vapor pressure of the evaporated material in a vacuum, i.e. the evaporated material is driven to the distribution pipe (and/or through the distribution pipe) by the evaporation pressure only (e.g. by the pressure originating from the evaporation of the material). For instance, no further means (such as fans, pumps, or the like) are used for driving the evaporated material to and through the distribution pipe. The distribution pipe

typically includes several nozzles for guiding the evaporated material to the vacuum chamber, in which the deposition takes place, or in which the material deposition arrangement is located during operation.

[0084] According to some embodiments, the method includes in box 530 guiding the evaporated material through a nozzle to the vacuum deposition chamber. The nozzle typically provides a passage wall and a passage channel surrounded by the passage wall. According to some embodiments, guiding the evaporated material through the nozzle includes guiding the evaporated material past at least two fins extending into the passage channel. In some embodiments, the guiding further includes guiding the evaporated material through a first stage of the nozzle having a first stage length and a first stage size, and guiding the evaporated material through a second stage having a second stage length and a second stage size, wherein the ratio of the second size to the first size is between 2 and 10. In one example, the ratio of the second size to the first size is about 4. According to some embodiments, the nozzle may be a nozzle as described in embodiments above, such as the embodiments shown and described in Figs. 1 to 5.

[0085] According to some embodiments, the method may further include influencing the uniformity of the evaporated material in the first stage of the nozzle and influencing the directionality of the evaporated material released to the vacuum chamber by the second stage of the nozzle. The ratio of the stage sizes may help to increase the uniformity of the evaporated material and the directionality of the evaporated material. For instance, the smaller size of the first stage, which the evaporated material passes at first, may force the evaporated material into an increased uniformity, e.g. regarding the material density, the material velocity, and/or the material pressure. According to some embodiments described herein, the second stage may increase the directionality by capturing the evaporated material spreading from the smaller cross-section of the first stage when leaving the first stage. Further, the directionality of the flow may be improved by the fins provided in the nozzle, as explained in detail above. The evaporated material may reach the substrate or pixel mask with a small spreading angle.

[0086] According to some embodiments, the described nozzle design in a material deposition arrangement according to embodiments described herein provides fins in the nozzle passage, and in particular further includes differently sized nozzle stages. The nozzle

having fins extending in the passage channel according to embodiments described herein may focus the material flow of an evaporated material to the substrate. The nozzle according to embodiments described herein is typically used to focus evaporated material in the gaseous phase from an evaporator source to a substrate within a vacuum chamber, e.g. for generating an OLED active layer on a substrate.

[0087] According to some embodiments, the absorption peak in the center of a deposition spot opposite to the nozzle could be about 45% higher compared to another nozzle with a single tube design without fins and without differently sized stages. Absorbent elements, such as an absorber stage or aperture, further allow cutting the material flow outside a +/- 30° angle nearly completely. The effect is an improvement, which could not be achieved in other nozzles. In other systems, the distance between the nozzle and the substrate was increased in order to achieve a similar effect. However, the increased distance leads to a contamination of the chamber and to an increased material consumption. In other systems, an aperture plate is used for limiting the spreading angle of the vapor plume leaving the nozzle, which also results in an increased material consumption since the spread material lands on the aperture plate.

[0088] According to some embodiments, the use of a material source arrangement as described herein, and/or the use of a vacuum deposition system as described herein is provided.

[0089] While the foregoing is directed to some embodiments, other and further embodiments may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

CLAIMS

1. A nozzle (400) for being connected to a distribution pipe (106; 106a; 106b) for guiding evaporated material from a material source (102; 102a; 102b) into a vacuum chamber (110), the nozzle comprising:

a nozzle inlet (401) for receiving the evaporated material, a nozzle outlet (403) for releasing the evaporated material to the vacuum chamber (110), and a nozzle passage (402) between the nozzle inlet (401) and the nozzle outlet (403) along a length direction (460) of the nozzle (400),

wherein the nozzle passage (402) has a passage wall (404) surrounding a passage channel (405); and

wherein the nozzle (400) further comprises at least two fins (406) extending into the passage channel (405).

2. The nozzle according to claim 1, wherein the fins (406) are provided by a ring structure at the wall (404) of the nozzle passage (402).

3. The nozzle according to any of claims 1 to 2, wherein the fins (406) each extend in a fin extension plane having an angle of 75° to 105° relative to the length direction of the nozzle.

4. The nozzle according to any of claims 1 to 3, wherein the fins (406) have at least partially a shape along the length direction (460) of the nozzle (400) of one of the group consisting of: a triangle, a rectangle, a thread like shape, and a lamella-like shape.

5. The nozzle according to any of claims 1 to 4, wherein the nozzle passage (402) comprises n stages (410; 420; 430), wherein each of the stages has a larger size (411; 421; 431) perpendicular to the length direction (460) of the nozzle (400) than the preceding stage in a direction from the nozzle inlet (401) to the nozzle outlet (403); and

wherein in particular each stage (410; 420; 430) provides an equally large or larger conductance value than that of the preceding stage in a direction from the nozzle inlet (401) to the nozzle outlet (403).

6. The nozzle according to any of claims 1 to 5, wherein the nozzle (400) has a first stage (410) having a first dimension (411) perpendicular to the length direction (460) of the nozzle (400) and a second stage (420) having a second dimension (421) perpendicular to the length direction (460) of the nozzle (400), wherein the second dimension (421) is larger than the first dimension (411); and

wherein the fins (406) are provided in the second stage (420) or between the first stage (410) of the nozzle (400) and the second stage (420) of the nozzle (400).

7. The nozzle according to claim 6, wherein the fins (406) encompass a third dimension perpendicular to the length direction (460) of the nozzle (400) being larger than the first dimension.

8. The nozzle according to any of claims 1 to 7, wherein the nozzle (400) is configured for guiding an evaporated organic material having a temperature between about 100 °C and about 600°C to the vacuum chamber (100).

9. The nozzle according to any of claims 1 to 8, wherein the nozzle (400) is configured for a mass flow of less than 1 sccm, and/or wherein the nozzle passage (402) has a minimum dimension of less than 15 mm.

10. A material source arrangement (100) for depositing a material on a substrate (121) in a vacuum deposition chamber (110), comprising:

a distribution pipe (106; 106a; 106b) being configured to be in fluid communication with a material source (102; 102a; 102b) providing the material to the distribution pipe (106; 106a; 106b); and

at least one nozzle (400) according to any of claims 1 to 9.

11. The material source arrangement according to claim 10, wherein the material source (102; 102a; 102b) is a crucible for evaporating material and wherein the distribution pipe (106; 106a; 106b) is a linear distribution pipe.

12. A vacuum deposition system (300), comprising:

a vacuum deposition chamber (110);

a material source arrangement (100) according to any of claims 10 to 11 in the vacuum chamber (110); and

a substrate support for supporting the substrate (121) during deposition.

13. The vacuum deposition system according to claim 12, wherein the vacuum deposition system (300) further comprises a pixel mask (132) between the substrate support and the material source arrangement (102; 102a; 102b).

14. The vacuum deposition system according to claim 13, wherein the vacuum deposition system (300) is adapted for simultaneously housing two substrates (121) to be coated on two substrate supports within the vacuum deposition chamber (110);

wherein the material source arrangement (100) is arranged movably between the two substrate supports within the vacuum deposition chamber (110), the material source (102; 102a; 102b) of the material source arrangement being a crucible for evaporating organic material; and

wherein the pixel mask (132) comprises openings of less than 50 μm.

15. Method for depositing a material on a substrate (121) in a vacuum deposition chamber (110), comprising:

evaporating a material to be deposited in a crucible (102; 102a; 102b);

providing the evaporated material to a distribution pipe (106; 106a; 106b) being in fluid communication with the crucible (102; 102a; 102b); and

guiding the evaporated material through a nozzle (400) having a passage wall (404) surrounding a passage channel (405) between a nozzle inlet (401) and a nozzle outlet (403) to the vacuum deposition chamber (110);

wherein guiding the evaporated material through the nozzle (400) comprises guiding the evaporated material past at least two fins (406) extending into the passage channel (405).

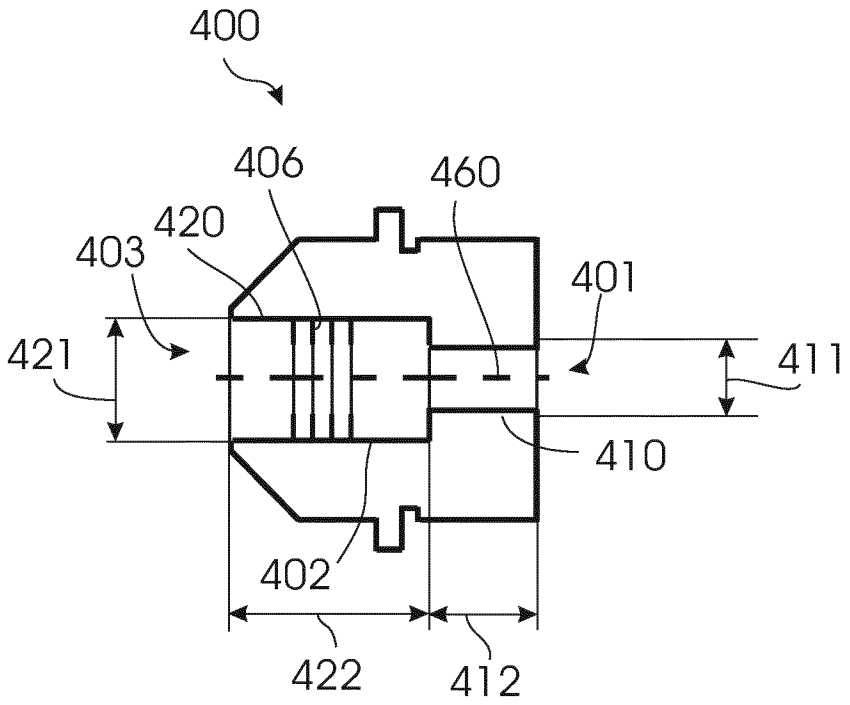


Fig. 1a

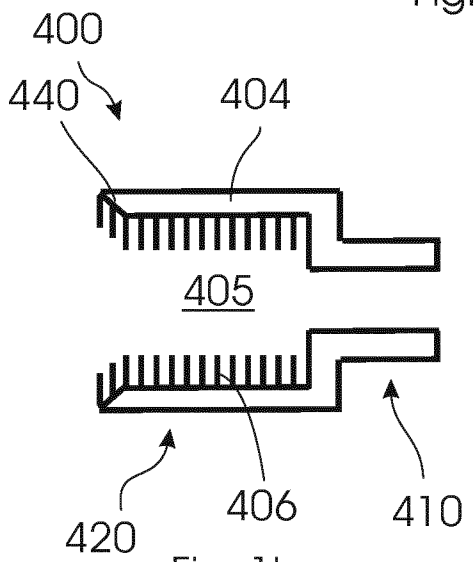


Fig. 1b

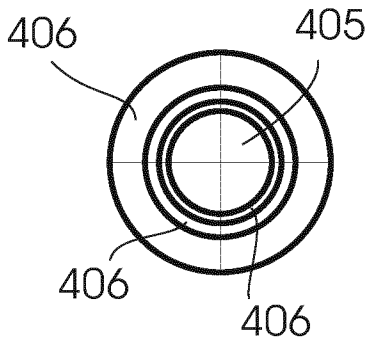


Fig. 1c

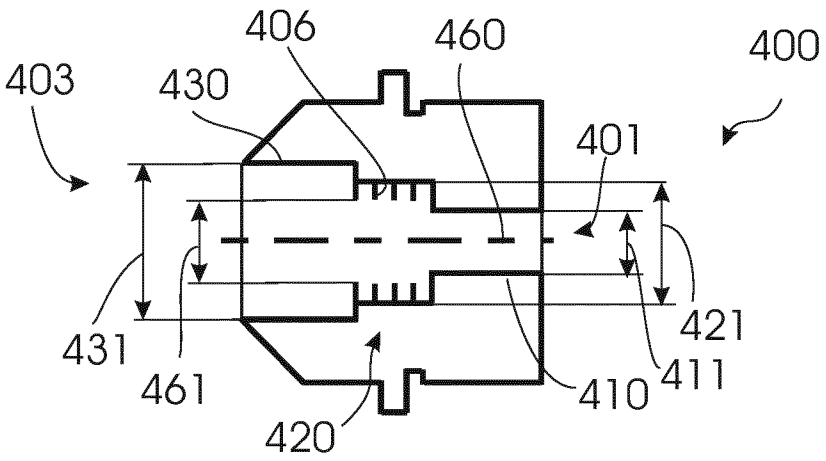


Fig. 2

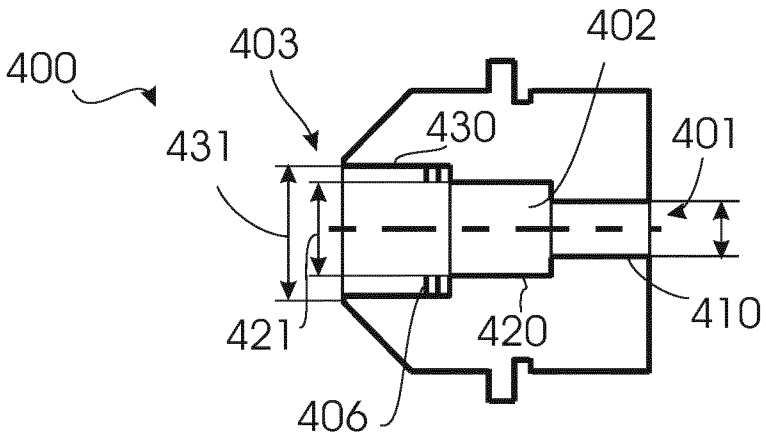


Fig. 3

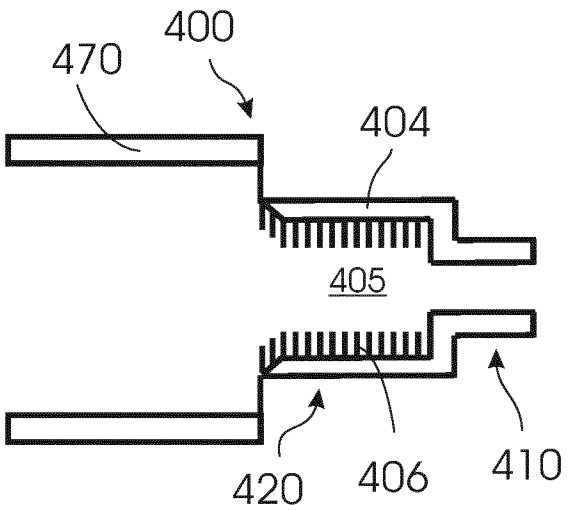


Fig. 4a

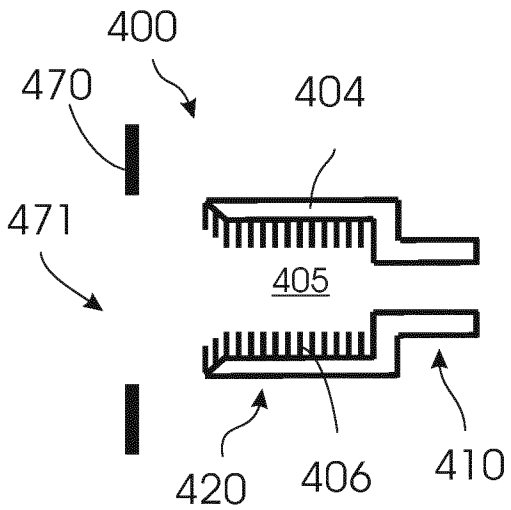


Fig. 4b

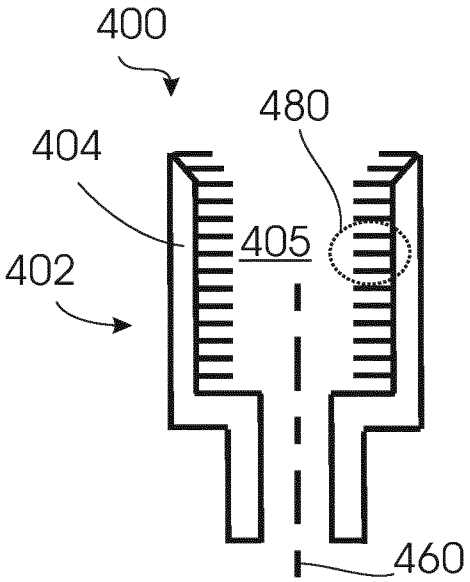


Fig. 5a

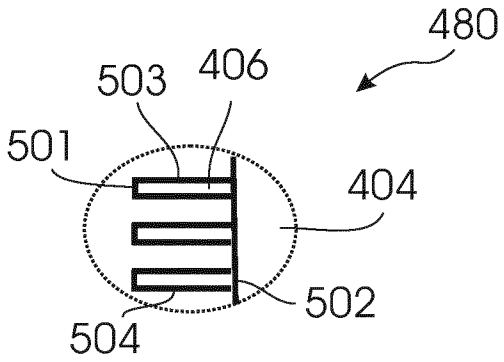


Fig. 5b

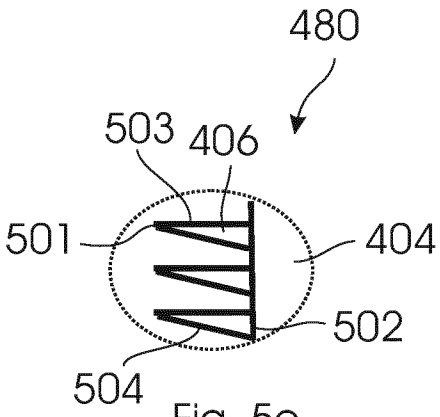


Fig. 5c

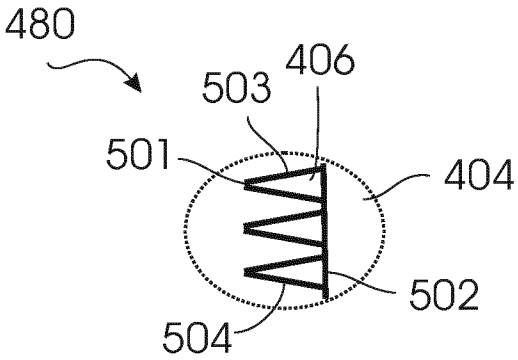


Fig. 5d

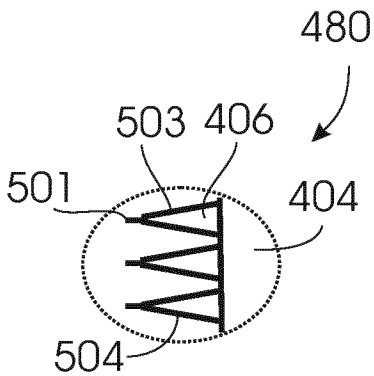


Fig. 5e

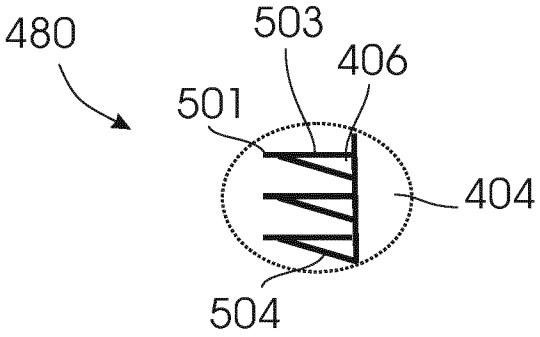


Fig. 5f

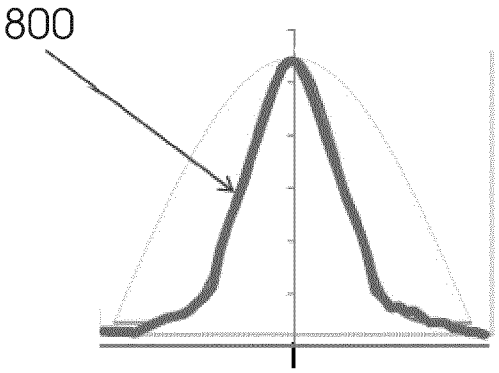


Fig. 6a

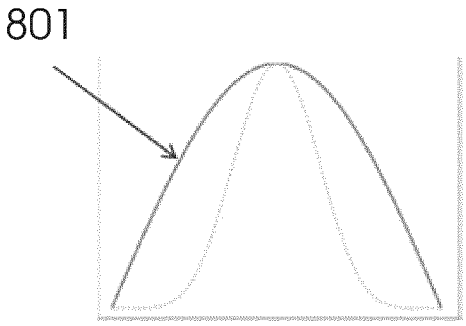


Fig. 6b

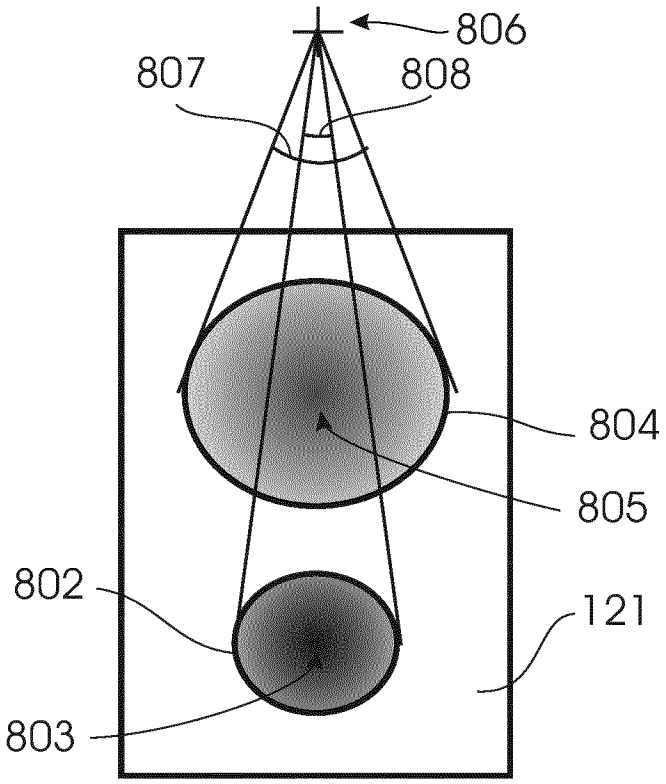


Fig. 7

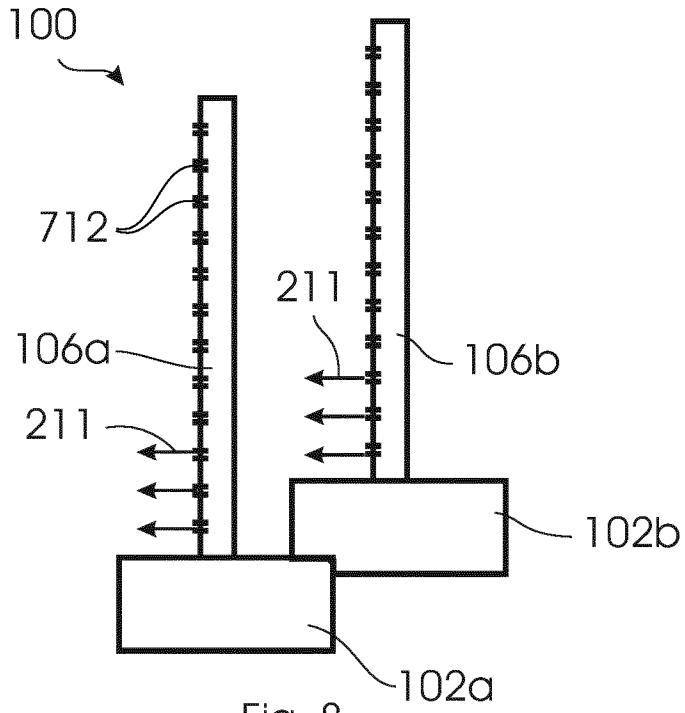

100
712
211
106a
106b
211
102b
102a

Fig. 8

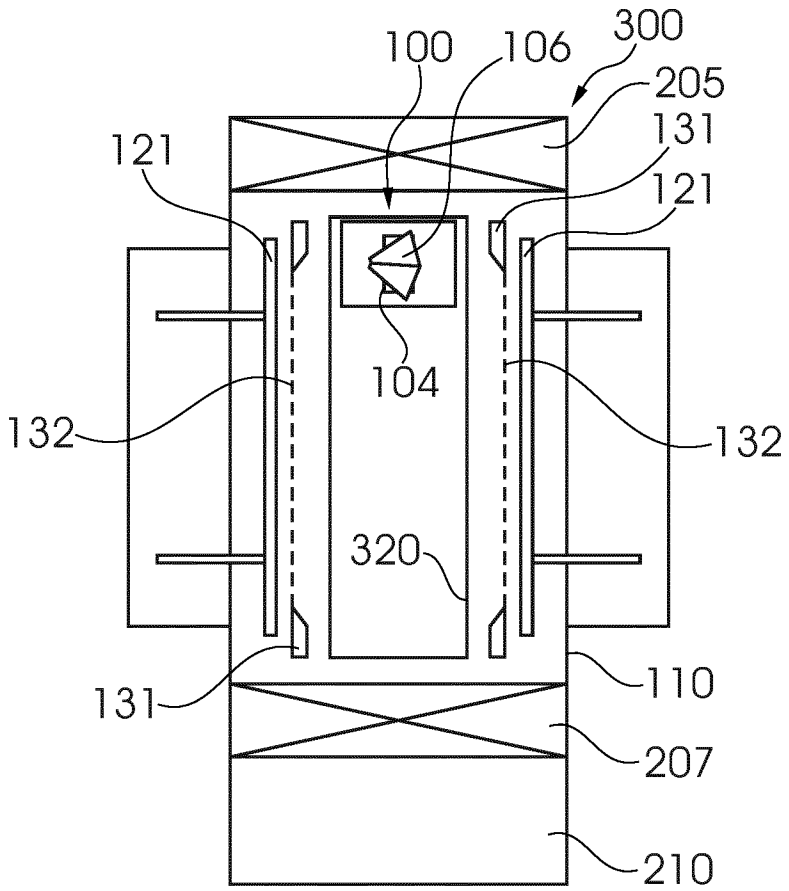

100
106
300
205
131
121
121
104
132
132
320
110
131
207
210

Fig. 9

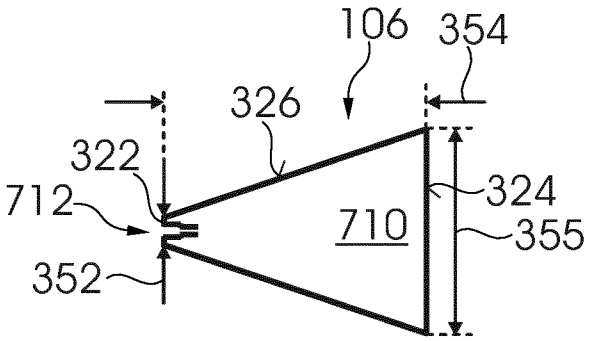


Fig. 10a

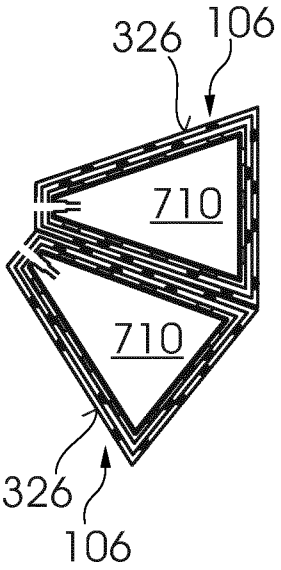


Fig. 10b

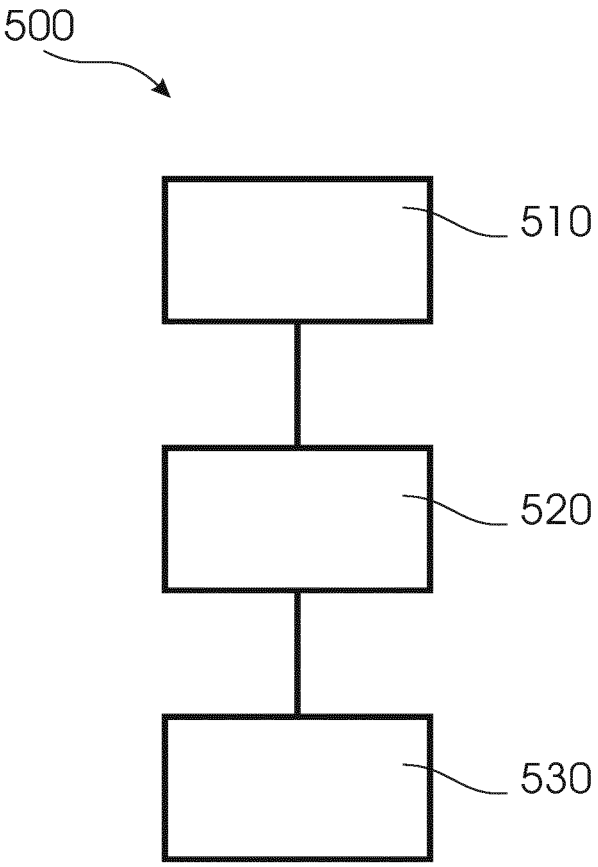


Fig. 11

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2015/057235

A. CLASSIFICATION OF SUBJECT MATTER
INV. C23C14/24 C23C14/12 C23C14/04
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

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)
EPO-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	US 2014/238299 A1 (CHO JA-HOON [KR]) 28 August 2014 (2014-08-28) paragraphs [0035] - [0042]; figures 1-6	1,3,4,8, 12
A	US 2010/159132 A1 (CONROY CHAD [US] ET AL) 24 June 2010 (2010-06-24) paragraphs [0036] - [0051]; figures 1-3	1-15
A	US 2013/291796 A1 (INOUE SATOSHI [JP] ET AL) 7 November 2013 (2013-11-07) paragraphs [0058] - [0112]; figures 1-13	1-15

☐ 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	Date of mailing of the international search report
19 October 2015	26/10/2015

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Patterson, Anthony

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2015/057235

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