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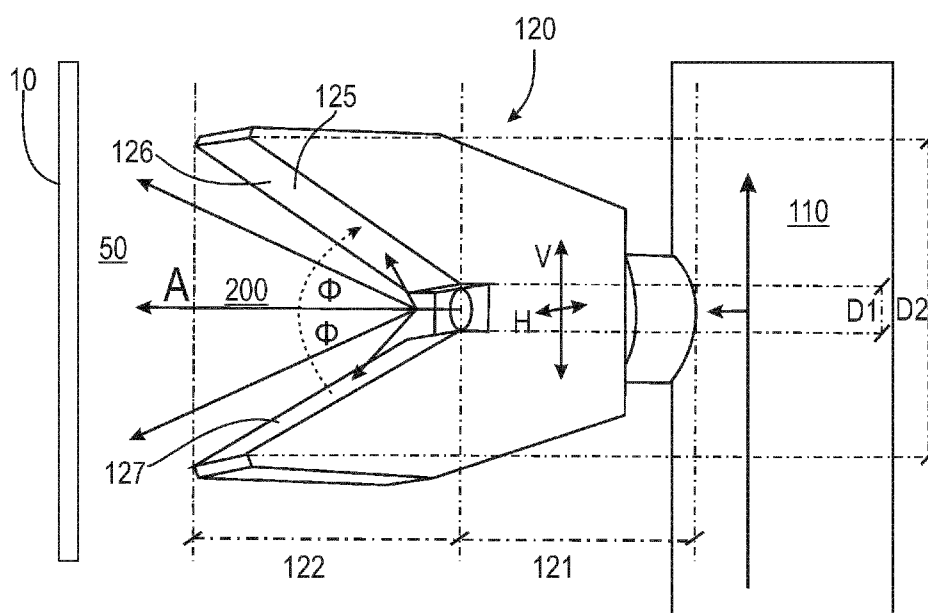


FIG. 2

(57) Abstract: Embodiments described herein relate to an evaporation source for depositing an evaporated material on a substrate. The evaporation source comprises a distribution pipe with a plurality of nozzles, wherein at least one nozzle of the plurality of nozzles comprises a first nozzle section configured to release a plume of evaporated material toward the substrate and a second nozzle section configured to shape the plume of evaporated material. The second nozzle section has a side wall providing a non-circular plume profile. According to a further aspect, a vacuum deposition system as well as a method of depositing an evaporated material on a substrate are described.



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**EVAPORATION SOURCE FOR DEPOSITING AN EVAPORATED MATERIAL,
VACUUM DEPOSITION SYSTEM, AND METHOD FOR DEPOSITING AN
EVAPORATED MATERIAL**

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TECHNICAL FIELD

[0001] Embodiments of the present disclosure relate to the deposition of materials on a substrate and to vacuum deposition systems for depositing materials on a substrate, e.g. organic materials. Embodiments of the present disclosure particularly relate to an evaporation source for depositing an evaporated material, e.g. an organic material, on a substrate, and particularly on a substrate which is essentially vertically oriented. Further embodiments relate to methods of depositing an evaporated material, e.g. an organic material, on a substrate. Embodiments particularly relate to the deposition of a pixel pattern on a substrate, particularly through a fine metal mask (FMM).

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BACKGROUND

[0002] Organic evaporators are a tool for the production of organic light-emitting diodes (OLEDs). OLEDs are a special type of light-emitting diode in which the emissive layer comprises a thin film of certain organic compounds. OLEDs are used in the manufacture of television screens, computer monitors, mobile phones and other hand-held devices 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 need 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 a manner 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.

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[0003] There are many challenges encountered in the manufacture of such display devices. OLED displays or OLED lighting applications include a stack of several materials, which are for example evaporated in a vacuum system. The organic materials are typically deposited in a predetermined pattern that is defined by a shadow mask. For the fabrication of OLEDs 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 in a crucible until the material evaporates. One or more distribution pipes guide the evaporated material to nozzles which may be provided in a wall of the distribution pipes. The nozzles direct the evaporated material toward the substrate. In recent years, the precision of the deposition process has been increased, e.g. allowing for smaller and smaller pixel sizes. In some processes, masks are used for defining the pixel pattern when the evaporated material passes through the mask openings. However, shadowing effects of the masks and the spread of the evaporated material make it difficult to increase the precision and the predictability of the evaporation process.

[0005] In view of the above, an increased precision and predictability of evaporation processes for manufacturing high quality devices, particularly high quality OLED displays, would be beneficial.

SUMMARY

[0006] In light of the above, an evaporation source for depositing an evaporated material on a substrate, a vacuum deposition system, as well as a method for depositing an evaporated material on a substrate are provided.

[0007] According to an aspect of the present disclosure, an evaporation source for depositing an evaporated material on a substrate is provided. The evaporation source includes a distribution pipe with a plurality of nozzles, wherein at least one nozzle of the plurality of nozzles has a first nozzle section configured to release a plume of evaporated material toward the substrate and a second nozzle section downstream of the first nozzle section configured to shape the plume of evaporated material. The second nozzle section has a side wall providing a non-circular plume profile with respect to a central nozzle axis.

[0008] In some embodiments, the side wall is configured to limit an expansion of the plume in a first direction perpendicular to the central nozzle axis, particularly in an essentially vertical direction. A shielding device separate from the at least one nozzle may be additionally provided for limiting an expansion of the plume in a second direction perpendicular to the central nozzle axis, particularly in an essentially horizontal direction. “Essentially vertical” as used herein may encompass directions having an angle of 10° or less with respect to the direction of gravity. “Essentially horizontal” as used herein may encompass directions having an angle of 10° or less with respect to an exactly horizontal direction.

[0009] According to a further aspect of the present disclosure, a vacuum deposition system is provided. The vacuum deposition system includes a vacuum chamber, an evaporation source for depositing an evaporated material on a substrate provided in the vacuum chamber, and at least one of a first drive for moving the evaporation source in the vacuum chamber along a transportation path and a second drive for rotating the distribution pipe of the evaporation source. The evaporation source may be configured in accordance with any of the embodiments described herein.

[0010] According to a further aspect of the present disclosure, a method for depositing an evaporated material on a substrate in a vacuum chamber is provided. The method includes directing evaporated material toward the substrate by a plurality of nozzles of one or more distribution pipes, wherein a plume of evaporated material is released by a first nozzle section of at least one nozzle of the plurality of nozzles toward the substrate, and the plume is shaped by a side wall of a second nozzle section of the at least one nozzle providing a plume profile which is non-circular with respect to a central nozzle axis.

[0011] Further aspects, advantages and features of the present disclosure are apparent from the description and the accompanying drawings.

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 the present disclosure, briefly summarized above, may be had by reference to embodiments. The accompanying drawings relate to embodiments of the present disclosure and are described in the following:

[0013] FIG. 1 shows a cross-sectional view of an evaporation source according to embodiments described herein in a vertical sectional plane;

[0014] FIG. 2 shows an enlarged view of a nozzle of the evaporation source of FIG. 1;

[0015] FIG. 3 shows a horizontal view of an evaporation source according to embodiments
5 described herein in a horizontal sectional plane;

[0016] FIGS. 4A-C show subsequent stages of a method for depositing an evaporated material on a substrate with a vacuum deposition system according to embodiments described herein; and

[0017] FIG. 5 is a flow diagram illustrating a method for depositing an evaporated material
10 on a substrate according to embodiments described herein.

DETAILED DESCRIPTION OF EMBODIMENTS

[0018] Reference will now be made in detail to the various embodiments of the present disclosure, one or more examples of which are illustrated in the figures. Within the following description of the drawings, the same reference numbers refer to the same components.
15 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 of the present disclosure. 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.

20 [0019] As used herein, the term “evaporated material” may be understood as a material that is evaporated and deposited on a surface of a substrate. For example, the evaporated material may be an organic material that is deposited on a substrate to form an optically active layer of an OLED device. The material may be deposited in a predetermined pattern, e.g. by using a mask such as a fine metal mask (FMM) having a plurality of openings. A plurality of pixels
25 may be deposited on the substrate. Other examples of evaporated materials include one or more of the following: ITO, NPD, Alq₃, Quinacridone, and metals such as silver or magnesium.

[0020] As used herein, the term “evaporation source” may be understood as an arrangement providing the evaporated material to be deposited on a substrate. In particular, the evaporation

source may be configured to direct an evaporated material to be deposited on a substrate into a deposition area in a vacuum chamber. The evaporated material may be directed toward the substrate via a plurality of nozzles of the evaporation source. The nozzles may have nozzle outlets, respectively, which may be directed toward the deposition area, particularly toward the substrate to be coated.

[0021] The evaporation source may include an evaporator (or “crucible”) which evaporates the material to be deposited on the substrate, and a distribution pipe, which is in fluid connection with the crucible and which is configured to guide the evaporated material to the plurality of nozzles for releasing plumes of evaporated material into the deposition area in a vacuum chamber.

[0022] In some embodiments, the evaporation source includes two or more distribution pipes, wherein each distribution pipe includes a plurality of nozzles. For example, each distribution pipe includes two or more nozzles, particularly ten or more nozzles, more particularly 30 or more nozzles. The nozzles of one distribution pipe may be arranged in a linear array or row, such that a line source is provided. In some embodiments, the evaporation source includes two or more distribution pipes arranged next to each other, wherein each of the two or more distribution pipes includes ten or more nozzles arranged in a row.

[0023] As used herein, the term “crucible” may be understood as a device or a reservoir providing or containing the material to be evaporated. Typically, the crucible may be heated for evaporating the material to be deposited on the substrate. According to embodiments herein, the crucible may be in fluid communication with the distribution pipe to which the evaporated material is delivered.

[0024] The term “distribution pipe” may be understood as a tube or pipe for guiding and distributing the evaporated material. In particular, the distribution pipe may guide the evaporated material from a crucible to the plurality of nozzles which may extend through a side wall of the distribution pipe. A plurality of nozzles typically includes at least two or more nozzles, each nozzle including a nozzle outlet for emitting a plume of evaporated material toward the substrate along a main emission direction which may correspond to a central nozzle axis. According to embodiments described herein, the distribution pipe may be a linear distribution pipe extending in a longitudinal direction, particularly in an essentially vertical direction. In some embodiments, the distribution pipe may include a pipe having a sectional

shape of a cylinder. The cylinder may have a circular bottom shape or any other suitable bottom shape, e.g. an essentially triangular bottom shape. In particular, the distribution pipe may have an essentially triangular sectional shape.

[0025] In some embodiments, the evaporation source may include two or three distribution pipes which extend in an essentially vertical direction, respectively. Each distribution pipe may be in fluid connection with a respective crucible such that different materials can be co-deposited on the substrate. Nozzles of a first distribution pipe and nozzles of an adjacent second distribution pipe may be arranged close to each other, e.g. at a distance of 5 cm or less, as is schematically depicted in FIG. 4A.

[0026] FIG. 1 is a sectional view of an evaporation source 100 for depositing an evaporated material on a substrate 10 according to embodiments described herein. The evaporation source 100 includes a distribution pipe 110 which may extend in an essentially vertical direction. Alternatively, the distribution pipe may extend in another direction, e.g. an essentially horizontal direction. In the embodiment depicted in FIG. 1, the distribution pipe 110 provides an essentially vertical line source. An essentially vertically extending distribution pipe may be beneficial because the footprint of the system can be reduced, and a compact and space-saving deposition system can be provided. In some embodiments, the evaporation source 100 includes two or more distribution pipes which are supported on a source support 105 which may be movable. The two or more distribution pipes may extend in an essentially vertical direction, respectively.

[0027] The distribution pipe 110 includes a plurality of nozzles 115 which may extend through a wall of the distribution pipe 110. The plurality of nozzles 115 allow the evaporated material to be directed from an interior space of the distribution pipe 110 into a deposition area 50 in a vacuum chamber where the substrate 10 is arranged. In some embodiments, ten or more nozzles, particularly thirty or more nozzles may be provided at the distribution pipe 110. The plurality of nozzles 115 may be arranged along the longitudinal direction of the distribution pipe 110 in a line setup.

[0028] The plurality of nozzles 115 may have a nozzle channel, respectively, which extends along a central nozzle axis (A) of the respective nozzle toward the deposition area 50 and defines the main evaporation direction of the respective nozzle. In some embodiments, the central nozzle axis (A) may extend in an essentially horizontal direction toward the substrate.

A plurality of plumes of evaporated material can be directed from the interior space of the distribution pipe 110 through the plurality of nozzles 115 toward the substrate 10.

[0029] In implementations, a mask may be arranged between the evaporation source 100 and the substrate 10, wherein the mask may be a FMM with an opening pattern which defines a pixel pattern to be deposited on the substrate. For example, the mask may have 100,000 openings or more, particularly 1,000,000 openings or more.

[0030] Conventional nozzles have a cylindrical nozzle channel configured to direct plumes of evaporated material having a circular cross-section toward the substrate. However, cylindrical nozzles may lead to a large spread of the evaporated material which may negatively affect the pixel precision, e.g. due to a shadowing effect of the mask on material evaporated at large emission angles. The shape of the nozzle defines the shape of the plume of evaporated material that is directed toward the substrate. It is challenging to shape the plume in such a way that the shadowing effect of the mask is small and it is still possible to arrange two or more nozzles close to each other, allowing for a co-evaporation of evaporated materials. Further, cleaning of the nozzles and/or of other components in the deposition area may be time-consuming and costly. It would be beneficial to reduce the cleaning time of the nozzles and increase the up-time of the system.

[0031] According to embodiments described herein, at least one nozzle 120 of the plurality of nozzles 115 includes a first nozzle section 121 configured to release a plume 200 of evaporated material toward the substrate 10 and a second nozzle section 122 configured to shape the plume 200 of evaporated material with a side wall 125 providing a non-circular plume profile with respect to the central nozzle axis (A).

[0032] In other words, the at least one nozzle 120 has a first nozzle section 121 which provides the plume of evaporated material and directs the plume toward the substrate, and a second nozzle section 122 downstream of the first nozzle section 121 which shapes the plume 200 in a predefined way. The second nozzle section 122 has a side wall 125 which is not circularly symmetric with respect to the central nozzle axis such that a non-circular plume provide is formed by the side wall 125.

[0033] In some embodiments, each nozzle of the plurality of nozzles 115 may have a corresponding setup, i.e. includes a respective first nozzle section configured to release a

plume toward the substrate, and a respective second nozzle section downstream of the first nozzle section with a side wall providing a non-circular plume profile. The side walls of the nozzles individually shape the plume of evaporated material of one associated nozzle, respectively. In particular, each nozzle of the plurality of nozzles may have a respective side wall for individually shaping the plume emanating therefrom to provide a plurality of non-circular plume profiles.

[0034] In particular, the plurality of nozzles 115 of the distribution pipe 110 may have the same configuration as the at least one nozzle 120. In some embodiments, the evaporation source may include two, three or more distribution pipes arranged next to each other on a common source support and extending in a longitudinal direction, respectively. The nozzles of two adjacent distribution pipes may be tilted such as to be directed to essentially the same deposition spot on the substrate. The pluralities of nozzles of the two or more distribution pipes may have essentially the same configuration as the at least one nozzle 120.

[0035] A non-circular plume profile is provided by the side wall 125 of the second nozzle section. In other words, in a sectional plane perpendicular to the central nozzle axis (A), the plume dimension downstream of the side wall 125 in a first direction, e.g. in a vertical direction (V), is different from the plume dimension in a second direction perpendicular to the first direction, e.g. in a horizontal direction (H).

[0036] This may allow a limitation of the spread of the plume 200 in the first direction which reduces the shadowing effect of the mask 11 and increases the pixel quality. For example, the shadow of a pixel edge of a deposited pixel may have a dimension of 3 μm , particularly 2.5 μm or less in a direction in which the plume is shaped by the second nozzle section. Yet, a comparatively high utilization of material can be achieved, since the material does not condense on the at least one nozzle due to the high nozzle temperature.

[0037] The first direction may be parallel to the longitudinal direction of the distribution pipe 110, i.e. parallel to the nozzle row direction in which the plurality of nozzles of the distribution pipe are arranged next to each other, forming a row of nozzles. Limiting an expansion of the plume 200 in a direction corresponding to the longitudinal direction of the distribution pipe 110 by the side wall 125 of the nozzle may be beneficial, since there may not be enough space to provide a separate shielding device between two adjacent nozzles of one distribution pipe. In particular, the second nozzle section 122 may shape the plume in the

nozzle row direction, which may be an essentially vertical direction. The side wall 125 of the second nozzle section 122 may have an upper side wall section and a lower side wall section arranged below the upper side wall section, wherein a passage for the plume 200 is formed between the upper side wall section and the lower side wall section.

5 [0038] The spread of the plume 200 in a second direction perpendicular to the first direction may be limited by the side wall 125 to a lesser degree. The second direction may be perpendicular to the longitudinal direction of the distribution pipe, i.e. perpendicular to the nozzle row direction. In particular, the second direction may be an essentially horizontal direction (H) perpendicular to the central nozzle axis (A). In particular, the side wall 125 may
10 not significantly restrict an expansion of the plume 200 in the second direction which may be a horizontal direction (H). This may allow an arrangement of nozzles of adjacent distribution pipes in close vicinity next to each other in the second direction, since no side wall of the nozzle may prevent an adjacent nozzle to be arranged next to the at least one nozzle 120 in the second direction.

15 [0039] It is noted that, in some embodiments, the evaporation source may include a first distribution pipe with a first plurality of nozzles and a second distribution pipe with a second plurality of nozzles arranged next to the first distribution pipe, wherein a shielding wall (not depicted in FIG. 1) separate from the nozzles may be arranged between the first plurality of
20 nozzles and the second plurality of nozzles and/or between the plumes emitted therefrom. The shielding wall may extend in an essentially vertical direction (i.e. in the first direction) between the first plurality of nozzles and the second plurality of nozzles, and/or the shielding wall may be thermally isolated from the nozzles. The shielding wall may limit the expansion of the plumes emitted by the first plurality of nozzles in the second direction, i.e. toward the plumes emitted by the second distribution pipe. Further, the shielding wall may limit the
25 expansion of the plumes emitted by the second plurality of nozzles in the second direction, i.e. toward the plumes emitted by the first distribution pipe.

[0040] In some embodiments, which may be combined with other embodiments described herein, the side wall 125 may limit an expansion of the plume 200 in a first direction, particularly in an essentially vertical direction (V), and/or may limit an expansion of the
30 plume 200 in a second direction, particularly in an essentially horizontal direction (H), to a lesser degree, or not at all. The first direction may be parallel to the longitudinal direction of the distribution pipe 110 and perpendicular to the central nozzle axis (A). The second

direction may be perpendicular to the longitudinal direction of the distribution pipe 110 and perpendicular to the central nozzle axis (A).

[0041] An asymmetric shaping of the plume 200 by the side wall 125 of the nozzle which is not circularly symmetric with respect to the central nozzle axis (A) may provide the following advantages: A first dimension of the plume profile can be shaped to be different from a second dimension of the plume profile; the shadowing effect of a mask can be reduced to a first extent in the first direction and to a second extent in the second direction; the maximum emission angle of the nozzle in a first sectional plane can be shaped to be different from the maximum emission angle of the nozzle in a second sectional plane; an adjacent nozzle of an adjacent distribution pipe can be provided very close to the nozzle in the second direction where the downstream section of the nozzle may not have a side wall.

[0042] FIG. 2 shows an enlarged perspective view of the at least one nozzle 120 of the evaporation source 100 of FIG. 1.

[0043] As is shown in FIG. 2, the first nozzle section 121 and the second nozzle section 122 may be in thermal contact and/or may be integrally formed, e.g. integrally provided as a one-piece component.

[0044] The plurality of nozzles of an evaporation source are typically directly or indirectly heatable by a heating device and/or are in thermal contact with the distribution pipe. During deposition, the temperature of the nozzles is typically hot, i.e. equal to or higher than the evaporation temperature of the evaporated material, in order to prevent a condensation of the evaporated material on a nozzle surface. A condensation of evaporated material on a nozzle surface may lead to a decrease in the width of the nozzle diameter due to material accumulation and finally to a clogging of the nozzle.

[0045] By arranging the second nozzle section 122 in thermal contact with the first nozzle section 121, both nozzle sections can be maintained at a similar (hot) temperature suitable for avoiding a condensation of the evaporated material on a nozzle surface. For example, the first nozzle section and the second nozzle section may be made of a thermally conductive material, such as metal, and be in direct contact with each other. In the embodiment depicted in FIG. 2, the first nozzle section and the second nozzle section are integrally formed. For example, the nozzle including the first nozzle section 121 and the second nozzle section 122 may be

provided as a one-piece component, e.g. made of metal. Similar temperatures of the first nozzle section and of the second nozzle section during deposition can be guaranteed.

[0046] In some implementations, the first nozzle section 121 is in thermal contact with a heated portion of the distribution pipe 110, e.g. with a wall of the distribution pipe. The heated portion of the distribution pipe is heatable by a heating device, e.g. to a temperature of 100°C or more, particularly 300°C or more, more particularly 500°C or more. The second nozzle section 122 may be in thermal contact with the first nozzle section 121. Accordingly, the second nozzle section 122 may be indirectly heated via the distribution pipe 110 and the first nozzle section 121. A condensation of evaporated material on the first nozzle section 121 and on the second nozzle section 122 can be reduced or avoided.

[0047] In some embodiments, which may be combined with other embodiments described herein, the first nozzle section 121 may include a nozzle channel for the evaporated material which is surrounded by a circumferential wall, and an outlet opening directed toward the deposition area 50 for releasing the plume 200 of evaporated material toward the substrate. For example, the first nozzle section 121 may provide a tubular channel for the evaporated material, particularly an essentially cylindrical channel, wherein the tubular channel may have a diameter from 0.1 mm to 15 mm, particularly from 1 mm to 12 mm, more particularly from 2 mm to 6 mm. The channel diameter may have an effect on the pressure inside the distribution pipe and, therefore, on the evaporation rate, as well as on the shape of the plume released by the outlet opening of the first nozzle section 121. A channel diameter between from 1 mm to 3 mm provides a suitable pressure gradient as well as a suitable deposition rate.

[0048] The side wall 125 of the second nozzle section 122 may provide a passage for the plume 200 having a dimension that expands in a direction away from the first nozzle section 121. In other words, the dimension of the passage may become larger in an emission direction. An expansion of the plume profile can be adapted as appropriate by a setting of the opening angle of the passage.

[0049] The side wall 125 is non-circular in sectional planes perpendicular to the central nozzle axis (A), as is depicted in FIG. 2. In particular, the side wall 125 may only partially surround the central nozzle axis (A) in sectional planes perpendicular to the central nozzle axis (A), such that an expansion of the plume profile is limited by the side wall 125 in the first direction perpendicular to the central nozzle axis (A), but not in the second direction

perpendicular to the central nozzle axis (A). As is schematically depicted in FIG. 2, the side wall 125 may limit a vertical expansion of the plume 200 to a first maximum emission angle Φ with respect to the central nozzle axis. On the other hand, no side wall of the nozzle may be arranged at the horizontal sides of the plume 200, such that a horizontal expansion of the plume may not be restricted by the side wall 125.

[0050] Providing a passage for the plume which gradually expands in one direction may be beneficial because the plume is not abruptly shaped or cut. The maximum plume emission angle may be defined by the expanding side wall, and evaporated particles having an emission angle greater than a maximum emission angle defined by the expanding side wall may be deflected by the side wall to propagate at a smaller angle with respect to the central nozzle axis (A) toward the substrate. In particular, the dimension of the passage provided by the side wall 125 may continuously expand in a direction away from the first nozzle section. More particularly, the dimension of the passage may linearly expand, such that a constant maximum emission angle may be defined by the side wall. Accordingly, the maximum emission angle can be set by an opening angle of the side wall as appropriate, and evaporated particles having an emission angle larger than the maximum emission angle can be deflected to become “paraxial” particles.

[0051] The dimension of the passage may continuously expand from a first dimension D1 close to the first nozzle section 121 to a second dimension D2 distant from the first nozzle section. The first dimension D1 may be 5 mm or less, and/or the second dimension D2 may be 10 mm or more. In some embodiments, the first dimension D1 is a vertical dimension of the passage close to the first nozzle section 121, and the second dimension is a vertical dimension of the passage distant from the first nozzle section 121. In some embodiments, the first dimension D1 and the second dimension D2 are dimensions of the passage in a direction parallel to the longitudinal direction of the distribution pipe 110.

[0052] In some implementations, the dimension of the passage expands in a vertical direction and/or in a direction parallel to the longitudinal direction of the distribution pipe. In particular, the side wall 125 may have an upper side wall section 126 and a lower side wall section 127 which are tilted with respect to the central nozzle axis (A), respectively, such that the dimension of the passage between the lower side wall section and the upper side wall section increases. In some embodiments, the vertical dimension of the passage continuously

increases in a direction along the central nozzle axis (A). The passage may have a wedge-shaped form which gradually opens toward the deposition area 50.

[0053] The upper side wall section 126 and the lower side wall section 127 may enclose therebetween an opening angle (2Φ) of 40° or more and 90° or less, particularly about 60° .

5 Thus, the maximum emission angle Φ of the plume 200 with respect to the central nozzle axis (A) may be 20° or more and 45° or less in a vertical sectional plane extending through the central nozzle axis (i.e. the vertical sectional plane depicted in FIG. 1). The shadowing effect of a mask can be reduced and sharp horizontal pixel edges can be provided.

[0054] In some embodiments, the side wall 125 is configured to limit an expansion of the
10 plume in a first direction parallel to the longitudinal direction of the distribution pipe. In particular, the side wall 125 is configured to limit a vertical expansion of the plume 200.

[0055] In some embodiments, the side wall 125 allows an essentially unrestricted expansion in a second direction perpendicular to the longitudinal direction of the distribution pipe. In particular, the side wall 125 is configured not to restrict a horizontal expansion of the plume.
15 Accordingly, an adjacent nozzle of an adjacent distribution pipe can be positioned at a close distance to the at least one nozzle 120 in the second direction. For example, a distance between the at least one nozzle and an adjacent nozzle of an adjacent distribution pipe may be 5 cm or less, particularly 4 cm or less, more particularly about 3 cm.

[0056] The second nozzle section 122 may provide a passage which limits only one
20 dimension of the plume, e.g. a vertical dimension of the plume. A horizontal dimension of the plume may not be limited by the second nozzle section 122 in at least some embodiments. For example, as is depicted in FIG. 2, the second nozzle section 122 limits an expansion of the plume in the vertical direction (V), but not in the horizontal direction (H), where the plume is allowed to expand.

25 [0057] A wedge-shaped passage may be provided by the second nozzle section 122 which expands toward the substrate 10. In some implementations, the wedge-shaped passage may have an essentially constant opening angle. In some implementations, an opening angle (2Φ) of the second nozzle section may be 40° or more and/or 90° or less.

[0058] In particular, the plurality of nozzles may have respective second nozzle sections
30 with fins provided in the longitudinal direction of the distribution pipe, i.e. in the nozzle row

direction. The fins may constitute the side walls of the second nozzle sections which shape the plume dimensions in the vertical direction (V).

[0059] The first nozzle sections of the plurality of nozzles may be provided with threads, such that the nozzles can be fixed at the distribution pipe, e.g. by screwing the plurality of
5 nozzles to the distribution pipe.

[0060] In some implementations, the second nozzle section 122 may have a length of 10 mm or more, particularly 15 mm or more, along the central nozzle axis (A). Alternatively or additionally, the first nozzle section 121 may have a length of 10 mm or more, particularly 15 mm or more, along the central nozzle axis. The length of the first nozzle section 121 may
10 correspond to a length of a nozzle channel surrounded by a circumferential wall of the nozzle and having an outlet opening for releasing the plume 200. The length of the second nozzle section is measured from the outlet opening of the first nozzle section to a projection of a front end of the side wall 125 on the central nozzle axis (A).

[0061] FIG. 3 shows a sectional view of an evaporation source 100 according to
15 embodiments described herein in a horizontal sectional plane. The sectional view of FIG. 3 shows a sectional profile of the distribution pipe 110 of the evaporation source 100 in a sectional plane perpendicular to the longitudinal direction of the distribution pipe. It is shown that the distribution pipe 110 may have an essentially triangular sectional shape. Other sectional shapes of the distribution pipe 110 are possible. As is depicted in FIG. 4A, an
20 essentially triangular shape of two or more distribution pipes allows a close arrangement of two nozzles of adjacent distribution pipes.

[0062] The sectional plane of FIG. 3 extends through the at least one nozzle 120 and shows the first nozzle section 121 being configured as a tubular passage with an outlet opening for releasing a plume 200 of evaporated material toward the substrate 10. Further, the second
25 nozzle section 122 downstream of the first nozzle section 121 is schematically depicted. The second nozzle section 122 may limit a vertical expansion of the plume 200 (not visible in FIG. 3) and may allow an essentially unrestricted expansion of the plume in a horizontal direction (H), as is visible in FIG. 3.

[0063] In particular, the second nozzle section 122 may include a wedge-shaped passage or
30 a passage having a shape corresponding to two opposing sections of a cone which restrict an

expansion of the plume in a vertical direction and allow a horizontal expansion of the plume 200.

[0064] Heating devices 108 for heating the distribution pipe 110 may be provided, such that an interior space of the distribution pipe can be maintained at a first temperature higher than an evaporation temperature of the evaporated material. A condensation of the evaporated material on an inner wall of the distribution pipe and on an inner wall of the at least one nozzle 120 can be avoided. The at least one nozzle 120 may be in thermal contact with a heated wall of the distribution pipe 110, such that both the first nozzle section 121 and the second nozzle section 122 can be held essentially at the first temperature.

[0065] In some embodiments, a cooling shield 106 may be provided for reducing the heat load toward the deposition area 50. The cooling shield 106 may surround an inner wall of the distribution pipe 110.

[0066] In some implementations, the first nozzle section 121 and the second nozzle section 122 may be in thermal contact or may be integrally formed as one single component, and may be in thermal contact with a heatable part of the distribution pipe.

[0067] In some embodiments, which may be combined with other embodiments described herein, the evaporation source 100 further includes a shielding device 300. The shielding device 300 may be provided as a component separate from the at least one nozzle 120 and may be configured to shape the plume 200 of evaporated material downstream of the second nozzle section 122. The shielding device 300 may be configured to shape the plume 200 in the second direction.

[0068] In particular, the side wall 125 of the second nozzle section 122 may be configured to shape the plume 200 in a first direction, particularly in a vertical direction (V), and the shielding device 300 may be configured to shape the plume 200 in a second direction different from the first direction, particularly in a horizontal direction (H). More particularly, the second nozzle section 122 may be configured to limit a vertical expansion of the plume 200, and the shielding device 300 may be configured to limit a horizontal expansion of the plume 200.

[0069] Thus, the at least one nozzle 120 itself may limit an expansion of the plume 200 in the first direction, particularly in a direction corresponding to the longitudinal direction of the

distribution pipe, and the shielding device 300 separate from the at least one nozzle 120 may limit an expansion of the plume 200 in a second direction perpendicular to the first direction downstream of the at least one nozzle 120. Providing two separate plume shaping components, i.e. the second nozzle section 122 and the shielding device 300, for shaping two different plume dimensions may be beneficial. In particular, by shaping the plume in two different directions perpendicular to the central nozzle axis (A), the shadowing effect of the mask may be reduced and pixels with sharp vertical and horizontal edges can be provided. Accordingly, the pixel density can be increased. For example, pixel edge requirements may be different for vertical pixel edges and horizontal pixel edges.

[0070] Shaping one dimension of the plume 200 with the nozzle may be particularly effective in the first direction in which the plurality of nozzles 115 is provided in the longitudinal direction of the distribution pipe. Shaping the plume 200 with a shielding device 300 separate from the plurality of nozzles may be particularly effective in the second direction in which adjacent nozzles of adjacent distribution pipes are arranged at a close distance, such that the plumes of two or more closely adjacent nozzles can be correspondingly shaped by a common shielding device (as is schematically depicted in FIG. 4A).

[0071] In some embodiments, which may be combined with other embodiments described herein, the evaporation source includes a first distribution pipe with a first plurality of nozzles and a second distribution pipe with a second plurality of nozzles arranged next to the first distribution pipe, and optionally further distribution pipes with further pluralities of nozzles provided on a common source support 105. Reference is made to the exemplary embodiment depicted in FIG. 4A which shows an evaporation source with two adjacent distribution pipes. A shielding wall 302 (schematically depicted in FIG. 4A) separate from the nozzles may be arranged between the first plurality of nozzles and the second plurality of nozzles and/or between the respective plumes emitted therefrom. The shielding wall 302 may extend in an essentially vertical direction (i.e. in the first direction) between the first plurality of nozzles and the second plurality of nozzles and/or between the plumes emitted from the first plurality of nozzles and the plumes emitted from the second plurality of nozzles. The shielding wall 302 may be thermally isolated from the nozzles. In particular, the shielding wall 302 may not be in thermal contact with any of the nozzles. Accordingly, the shielding wall 302 can be kept at a lower temperature than the pluralities of nozzles during evaporation. The shielding wall 302 may limit the expansion of the plumes emitted by the first plurality of nozzles in the

second direction, i.e. in the direction toward the plumes emitted by the second distribution pipe. Further, the shielding device may limit the expansion of the plumes emitted by the second plurality of nozzles in the second direction, i.e. in the direction toward the plumes emitted by the first distribution pipe. The shielding wall 302 may be provided as an integral part of the shielding device 300 or as a component separate from the shielding device 300. For example, the shielding device 300 depicted in FIG. 4A has three shielding walls, wherein an inner shielding wall is arranged between the nozzles of two adjacent distribution pipes, and two outer shielding walls are provided.

[0072] The nozzles of two or more distribution pipes may be configured in accordance with the at least one nozzle 120 described herein.

[0073] The shielding device 300 may be arranged spaced-apart from the at least one nozzle 120 and/or thermally isolated from the at least one nozzle 120. As is depicted in FIG. 3, a gap may be provided between the at least one nozzle 120 and the shielding device 300, the gap providing a thermal isolation between said two components. Accordingly, the shielding device 300 can be kept at a second temperature different from the first temperature of the at least one nozzle. In particular, the second temperature of the shielding device 300 may be lower than the first temperature of the at least one nozzle 120 during evaporation. The shielding device 300 may have a comparatively large surface area. Reducing the temperature of the shielding device 300 may substantially reduce the heat load of the evaporation source 100 toward the substrate 10. Thermal deformations of the mask 11 and/or of the substrate 10 during evaporation can be reduced, and the deposition accuracy can be increased.

[0074] In some embodiments, the at least one nozzle 120 including the first nozzle section 121 and the second nozzle section 122 may be maintained at a first (hot) temperature during evaporation. Condensation of evaporated material on the at least one nozzle 120 can be avoided, and cleaning of the at least one nozzle 120 can be facilitated. In particular, cleaning the nozzle at regular intervals may not be necessary when no material accumulates on the nozzle surface due to the high temperature thereof. It is noted that the accumulation of already a small amount of material on the nozzle surface may negatively affect the deposition result due to the small dimensions of the nozzle channel and of the nozzle passage.

[0075] In some embodiments, the shielding device 300 is maintained at a second (cold) temperature during evaporation which is smaller than the first temperature. Evaporated

material may accumulate on the surface of the shielding device 300 during evaporation over time. However, cleaning of the shielding device 300 at regular intervals is typically easy due to the large size of the shielding device 300. It is noted that the shielding device 300 is arranged downstream of the at least one nozzle where the plume 200 is larger. Further, at a position downstream of the at least one nozzle where the shielding device is arranged, the accumulation of material on the shielding device may only insignificantly affect the plume profile. Accordingly, the accumulation of evaporated material on the shielding device 300 may be acceptable.

[0076] Since the at least one nozzle 120 and the shielding device 300 are arranged spaced apart and/or thermally isolated from each other, a temperature difference of 50°C or more, particularly 100°C or more, more particularly 200°C or more between said components can be maintained during evaporation.

[0077] In some embodiments, which may be combined with other embodiments described herein, a cooling device 305 for cooling the shielding device 300 may be provided. The cooling device 305 may be configured for actively or passively cooling the shielding device 300. For example, the cooling device 305 may include cooling channels provided in or at the shielding device. A cooling circuit may be provided. In some embodiments, cooling lines for a cooling fluid, e.g. cooling water or cooling gas may be provided for cooling the shielding device 300.

[0078] In some implementations, the shielding device 300 includes two opposing shielding walls 301 extending on a front side of the distribution pipe 110 where the plurality of nozzles is arranged. The two opposing shielding walls 301 may be configured to limit an expansion of the plumes emitted by the plurality of nozzles of the distribution pipe 110. In particular, the two opposing shielding walls 301 may limit an expansion of the plumes in a direction perpendicular to the longitudinal direction of the distribution pipe 110, particularly the horizontal expansion of the plumes.

[0079] For example, in the horizontal sectional plane of FIG. 3, the shielding device 300 may limit the maximum emission angle θ of the at least one nozzle 120 with respect to the central nozzle axis (A) to an angle of 20° or more and/or 45° or less, particularly about 30°.

[0080] The shielding device 300 may be configured to shape a plurality of plumes emitted by the plurality of nozzles 115 of the distribution pipes. One single shielding device including the shielding walls may horizontally limit a plurality of plumes emitted by the plurality of nozzles of the distribution pipe 110.

5 [0081] In some embodiments, the shielding device 300 may be configured to shape pluralities of plumes emitted by the pluralities of nozzles of two or more adjacent distribution pipes, as is schematically depicted in FIG. 4A. In particular, nozzles of adjacent distribution pipes may be at least partially arranged between opposing shielding walls of the shielding device 300, respectively, such that the plumes emitted by the nozzles of two or more
10 distribution pipes are shaped by one shielding device having shielding walls 301.

[0082] In some implementations, the shielding device 300 may include an essentially C-shaped arrangement of shielding walls provided on the front side of the distribution pipe 110. The C-shaped arrangement may extend in the longitudinal direction of the distribution pipe on the front side of the distribution pipe, particularly in the vertical direction (V). The two
15 opposing shielding walls 301 may extend on two sides of the plurality of nozzles from the distribution pipe toward the substrate essentially in a direction essentially parallel to the central nozzle axes, as is schematically depicted in FIG. 3. The length L of the shielding device 300 in the direction of the central nozzle axis (A) is typically longer than the length of the second nozzle section 122 in the direction of the central nozzle axis (A), and/or the
20 distance of the two opposing shielding walls 301 from the central nozzle axis (A) is larger than the distance of the side wall 125 from the central nozzle axis (A). Accordingly, the plume 200 released by the first nozzle section 121 is first shaped by the side wall 125 in a first direction and subsequently shaped by the shielding device 300 in a second direction. In embodiments, the length L may be 20 mm or more.

25 [0083] The shielding device 300 may have a large surface which is directed toward the deposition area. When the shielding device 300 is cooled, thermal deformations of the mask 11 and/or the substrate 10 due to a heat load of the deposition source can be reduced, and the deposition accuracy can be improved. For example, the surface area of the shielding device 300 directed toward the substrate is more than twice the combined surface area of the plurality
30 of nozzles 115 directed toward the substrate. Accordingly, thermal deformations of the mask 11 and/or of the substrate due to an extensive heat load can be reduced. Further, the cleaning

of the shielding device 300 can be facilitated due to the large surface area of the shielding device 300.

[0084] FIG. 4A shows a schematic top view of a vacuum deposition system 400 including an evaporation source 100 according to embodiments described herein. The vacuum deposition system 400 includes a vacuum chamber 101 in which the evaporation source 100 is provided. According to some embodiments, which can be combined with other embodiments described herein, the evaporation source 100 is configured for a translational movement past the deposition area where the substrate 10 to be coated is arranged. Further, the evaporation source 100 may be configured for rotation around a rotation axis.

[0085] In particular, the evaporation source 100 may be configured for a translational movement in the second direction, i.e. in the horizontal direction (H), in which the expansion of the plumes released by the plurality of nozzles can be limited by the shielding device 300.

[0086] In some embodiments, the vacuum deposition system 400 may include at least one of a first drive 401 for moving the evaporation source 100 in the vacuum chamber 101 along a transportation path and a second drive 403 for rotating the distribution pipe 110 of the evaporation source 100. The distribution pipe 110 may be rotated from a first deposition area 50 where the substrate 10 and the mask 11 are arranged to a second deposition area 51 on an opposite side of the evaporation source 100 where a second substrate 20 and a second mask 21 can be arranged.

[0087] The evaporation source 100 may be configured in accordance with any of the embodiments described herein, such that reference can be made to the above explanations, which are not repeated here.

[0088] According to embodiments, the evaporation source 100 may have a crucible 102 or two or more crucibles, and a distribution pipe 110 or two or more distribution pipes. For instance, the evaporation source 100 shown in FIG. 4A includes two crucibles and two distribution pipes arranged next to each other. As is shown in FIG. 4A, a substrate 10 and a second substrate 20 are provided in the vacuum chamber 101 for receiving the evaporated material.

[0089] According to embodiments, a mask 11 for masking the substrate 10 can be provided between the substrate 10 and the evaporation source 100. The mask 11 may be held by a mask

frame in a predetermined orientation, particularly in an essentially vertical orientation. In embodiments, one or more tracks may be provided for supporting and displacing the mask 11. For instance, the embodiment shown in FIG. 4A has a mask 11 supported by a mask frame arranged between the evaporation source 100 and the substrate 10 and a second mask 21 supported by a second mask frame arranged between the evaporation source 100 and the second substrate 20. The substrate 10 and the second substrate 20 may be supported on respective transportation tracks in the vacuum chamber 101.

[0090] In embodiments, 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 $50\text{ }\mu\text{m} \times 50\text{ }\mu\text{m}$, or less. In one example, the pixel mask may have a thickness of about $40\text{ }\mu\text{m}$. During the evaporation, the mask 11 and the substrate 10 are typically in contact. Yet, considering the thickness of the mask and the size of the pixel openings, a shadowing effect may appear where the walls surrounding the pixel openings shadow an outer part of the pixel openings. The nozzles in combination with a shielding device 300 described herein may limit the maximum angle of impact of the evaporated material on the masks and on the substrates and reduce the shadowing effect. For example, a dimension of the shadow may become $3\text{ }\mu\text{m}$ or less according to deposition methods described herein.

[0091] According to embodiments described herein, the substrate may be coated with a material in an essentially vertical orientation. Typically, the distribution pipes are configured as line sources extending essentially vertically. In embodiments described herein, which can be combined with other embodiments described herein, the term “vertically” is understood, particularly when referring to the substrate orientation or the extension direction of the distribution pipe, to allow for a deviation from the vertical direction of 20° or less, e.g. of 10° or less. For example, this deviation can be provided because a substrate arranged with some deviation from a vertical orientation might result in a more stable deposition process. An essentially vertical substrate orientation during deposition of the material is substantially different from a horizontal substrate orientation. The surface of the substrate is coated by a line source extending in one direction corresponding to one substrate dimension and by providing a translational movement of the evaporation source along another direction corresponding to the other substrate dimension.

[0092] In some embodiments, the evaporation source 100 may be provided in the vacuum chamber 101 of the vacuum deposition system 400 on a track. The track is configured for the

translational movement of the evaporation source 100. According to different embodiments, which can be combined with other embodiments described herein, a first drive 401 for the translational movement of the evaporation source 100 may be provided at the track or at the source support 105. Accordingly, the evaporation source can be moved past the surface of the substrate to be coated during deposition, particularly along a linear path. Uniformity of the deposited material on the substrate can be improved.

[0093] As is schematically depicted in FIG. 4B, the evaporation source may move along the source transportation path past the substrate to be coated, particularly in the horizontal direction (H). A thin pattern of material can be evaporated on the substrate during the movement of the source from the source position depicted in FIG. 4A to the source position depicted in FIG. 4B. The expansions of the plumes of evaporated material may be limited in the horizontal direction H by the shielding device 300 which may be provided separate from and at a different temperature from the plurality of nozzles. The expansions of the plumes of evaporated material may be limited in the vertical direction by the nozzles themselves which have a second nozzle section with a side wall for shaping the plumes in a vertical direction, respectively. Accordingly, the shadowing effect of the mask can be reduced in both dimensions of the substrate surface.

[0094] As is schematically depicted in FIG. 4C, the distribution pipes of the evaporation source 100 may rotate, e.g. by an rotation angle of about 180° , around a vertical rotation axis, to be directed toward the second deposition area 51 where the second substrate 20 is arranged. Coating may continue on the second substrate 20 in the second deposition area 51 of the vacuum chamber 101 by moving the evaporation source along the source transportation path back to the source position depicted in FIG. 4A.

[0095] The vacuum deposition system 400 may be used for various applications, including applications for OLED device manufacturing including processing methods, wherein two or more source materials such as, for instance, two or more organic materials are evaporated simultaneously. In the example shown in FIG. 4A to FIG. 4C, two or more distribution pipes and corresponding crucibles are provided next to each other on the source support 105 which is movable. For example, in some embodiments, three distribution pipes may be provided next to each other, each distribution pipe including a plurality of nozzles with respective nozzle outlets for releasing the evaporated material from the interior of the respective distribution pipe into the deposition area of the vacuum chamber. The nozzles may be

provided along the longitudinal direction of the respective distribution pipe, e.g. at an equal spacing. At least some distribution pipes may be configured for introducing a different evaporated material into the deposition area of the vacuum chamber.

[0096] 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 0.5 m² or more, particularly 1 m² or more. 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 m² substrates (1.1 m x 1.3 m), GEN 7.5, which corresponds to about 4.29 m² substrates (1.95 m x 2.2 m), GEN 8.5, which corresponds to about 5.7 m² substrates (2.2 m x 2.5 m), or even GEN 10, which corresponds to about 8.7 m² substrates (2.85 m x 3.05 m). Even larger generations such as GEN 11 and GEN 12 and corresponding substrate areas can similarly be implemented.

[0097] According to embodiments herein, which can be combined with other embodiments described herein, the substrate thickness can be from 0.1 mm to 1.8 mm, and the holding arrangement for the substrate can be adapted for such substrate thicknesses. 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 a 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.

[0098] According to some embodiments, which may be combined with other embodiments described herein, the evaporation source 100 may further include a material collection unit 405 which can be configured as a shielding wall. The material collection unit 405 may be arranged to collect evaporated material emitted from the evaporation source, when the evaporation source is in a rotated position, particularly during a rotation of the evaporation source 100 around a rotation axis.

[0099] According to some embodiments, which can be combined with other embodiments described herein, the plurality of nozzles is arranged such that the nozzle outlets define a main

emission direction that is essentially horizontal ($\pm 20^\circ$) and corresponds to the central nozzle axis. According to some embodiments, the main emission direction can be oriented slightly upward, e.g. to be in a range from horizontal to 15° upward, such as 3° to 7° upward. Similarly, the substrate can be slightly inclined to be substantially perpendicular to the evaporation direction, which may reduce the generation of particles.

[00100] Embodiments of operating an evaporation source described herein are provided for maintaining high deposition accuracy over a long time period, while at the same time preventing clogging of the plurality of nozzles.

[00101] A method of operating an evaporation source 100 is described with reference to FIG. 5.

[00102] FIG. 5 is a flow diagram illustrating a method 500 for depositing an evaporated material on a substrate 10 in a vacuum chamber 101. The material may be heated and evaporated in a crucible, and the evaporated material may propagate via a distribution pipe 110 into a deposition area through a plurality of nozzles 115 of the distribution pipe 110.

[00103] In box 510, evaporated material is directed toward the substrate by the plurality of nozzles 115. A plume 200 of evaporated material is released by a first nozzle section 121 of at least one nozzle 120 of the plurality of nozzles 115. In particular, plumes of evaporated material are released by pluralities of nozzles of adjacent distribution pipes toward the substrate, wherein the nozzles may be configured in a similar or corresponding way.

[00104] In box 520, the plume is shaped by a side wall 125 of a second nozzle section 122 of the at least one nozzle 120 downstream of the first nozzle section, providing a plume profile which is non-circular with respect to a central nozzle axis (A). In particular, the side wall 125 limits the expansion of the plume in a first direction corresponding to a longitudinal direction of the distribution pipe, particularly in a vertical direction (V). For example, a vertical expansion of the plume is limited by the side wall 125. The side wall may have two side wall sections or fins provided on two opposing sides of the plume and forming a passage for shaping the plume in one direction.

[00105] In optional box 530, an expansion of the plume in a second direction different from the first direction is limited at a position downstream of the at least one nozzle 120,

particularly with a shielding device 300. In particular, a horizontal expansion of the plume is limited by the shielding device 300 downstream from the at least one nozzle 120.

[00106] Downstream of the shielding device 300, the shaped plume propagates through openings of a mask, and the evaporated material is deposited on the substrate which is
5 arranged behind a mask.

[00107] In some embodiments, the at least one nozzle 120 has a first temperature and the shielding device 300 has a second temperature lower than the first temperature by 100°C or more, particularly by 200°C or more.

[00108] This written description uses examples to disclose the disclosure, including the best
10 mode, and also to enable any person skilled in the art to practice the described subject-matter, including making and using any devices or systems and performing any incorporated methods. While various specific embodiments have been disclosed in the foregoing, mutually non-exclusive features of the embodiments described above may be combined with each other. The patentable scope is defined by the claims, and other examples are intended to be
15 within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

CLAIMS

1. An evaporation source (100) for depositing an evaporated material on a substrate (10), comprising a distribution pipe (110) with a plurality of nozzles (115),
at least one nozzle (120) of the plurality of nozzles comprising a first nozzle section
5 (121) configured to release a plume (200) of evaporated material toward the substrate (10) and a second nozzle section (122) configured to shape the plume of evaporated material with a side wall (125) providing a non-circular plume profile with respect to a central nozzle axis (A).
2. The evaporation source of claim 1, wherein the first nozzle section (121) and the
10 second nozzle section (122) are in thermal contact or integrally provided as a one-piece component.
3. The evaporation source of claim 1 or 2, wherein the side wall (125) provides a passage for the plume having a dimension which expands in a direction away from the first nozzle section (121).
- 15 4. The evaporation source of claim 3, wherein the dimension of the passage continuously expands from a first dimension (D1), particularly about 5 mm or less, to a second dimension (D2), particularly about 10 mm or more.
5. The evaporation source of claim 3 or 4, wherein the dimension of the passage which expands is a vertical dimension, particularly wherein the side wall (125) has an upper side
20 wall section (126) and a lower side wall section (127) which are tilted with respect to the central nozzle axis and enclose therebetween an opening angle (2Φ) of 40° or more and 90° or less.
6. The evaporation source of any of claims 1 to 5, wherein the side wall (125) is configured to limit a vertical expansion of the plume (200).
- 25 7. The evaporation source of any of claims 1 to 6, wherein the side wall allows an essentially unrestricted horizontal expansion of the plume (200).
8. The evaporation source of any of claims 1 to 7, further comprising a shielding device (300) separate from the at least one nozzle (120) and configured to shape the plume (200)

downstream of the second nozzle section (122), particularly wherein the shielding device (300) is configured to limit an expansion of the plume in a second direction.

9. The evaporation source of claim 8, wherein the shielding device (300) is arranged spaced-apart and/or thermally isolated from the at least one nozzle (120).

5 10. The evaporation source of claim 8 or 9, further comprising a cooling device (305) for cooling the shielding device (300).

11. The evaporation source of any of claims 8 to 10, wherein the shielding device (300) comprises two opposing shielding walls (301) extending on a front side of the distribution pipe (110) and configured to limit an expansion of a plurality of plumes emitted from the
10 plurality of nozzles (115), particularly a horizontal expansion.

12. The evaporation source of any of claims 1 to 11, wherein the first nozzle section (121) provides a tubular channel for the evaporated material, particularly an essentially cylindrical channel having a diameter from 2 mm to 15 mm, and/or wherein the second nozzle section (122) provides a passage which limits one dimension of the plume.

15 13. The evaporation source of any of claims 1 to 12, comprising two or more distribution pipes arranged next to each other and extending in an essentially vertical direction, respectively, each distribution pipe of the two or more distribution pipes comprising a plurality of nozzles having the same configuration as the at least one nozzle (120).

14. A vacuum deposition system, comprising:

20 a vacuum chamber (101);

an evaporation source (100) provided in the vacuum chamber; and

at least one of a first drive for moving the evaporation source (100) in the vacuum chamber (101) along a transportation path and a second drive for rotating the distribution pipe (110) of the evaporation source.

25 15. A method for depositing an evaporated material on a substrate (10) in a vacuum chamber, the method comprising:

directing evaporated material toward the substrate (10) by a plurality of nozzles,

wherein a plume (200) of evaporated material is released by a first nozzle section (121) of at least one nozzle (120) of the plurality of nozzles, and the plume (200) is shaped by a side wall (125) of a second nozzle section (122) of the at least one nozzle providing a plume profile which is non-circular with respect to a central nozzle axis (A).

- 5 16. The method of claim 15, wherein a vertical expansion of the plume (200) is limited by the side wall (125) of the second nozzle section (122), the method further comprising:

limiting a horizontal expansion of the plume (200) by a shielding device (300) downstream and separate from the at least one nozzle (120).

- 10 17. The method of claim 16, wherein the at least one nozzle (120) has a first temperature and the shielding device (300) has a second temperature lower than the first temperature by 100°C or more.

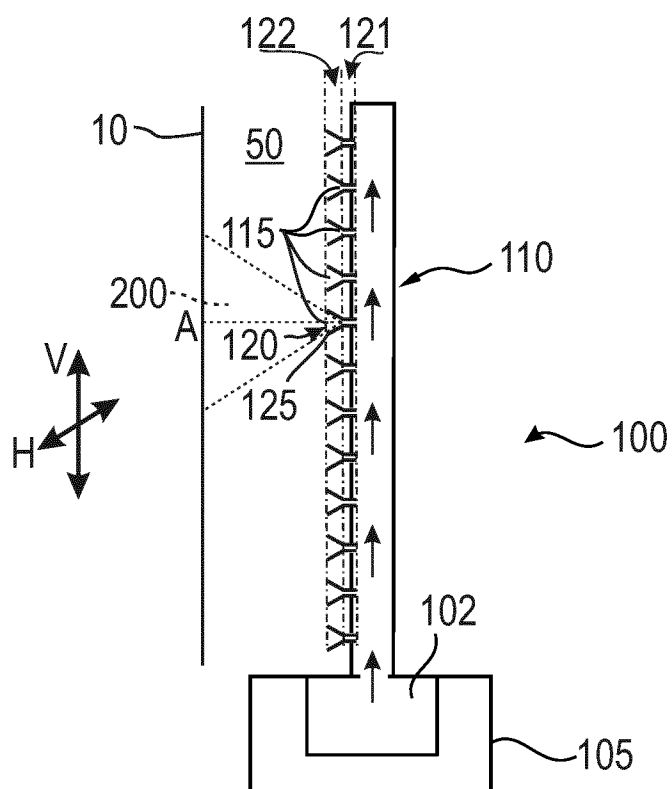


FIG. 1

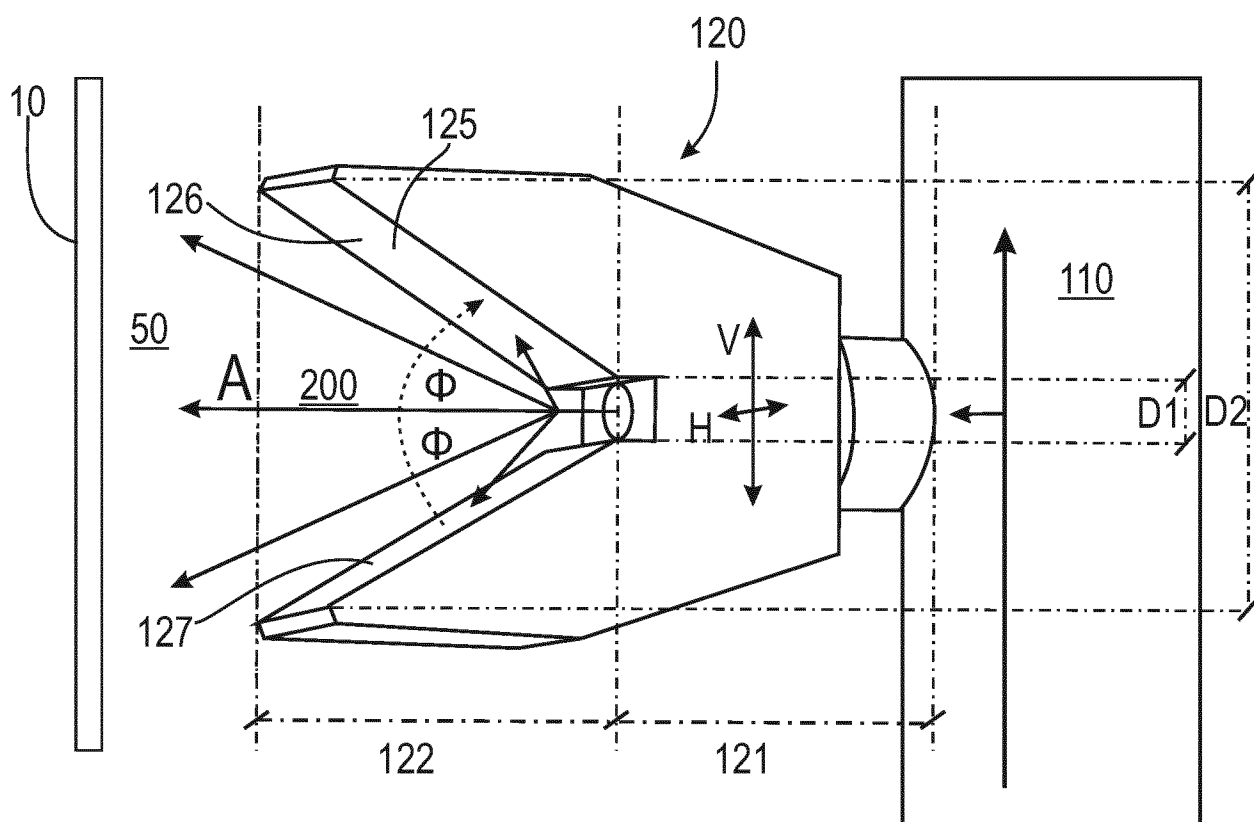


FIG. 2

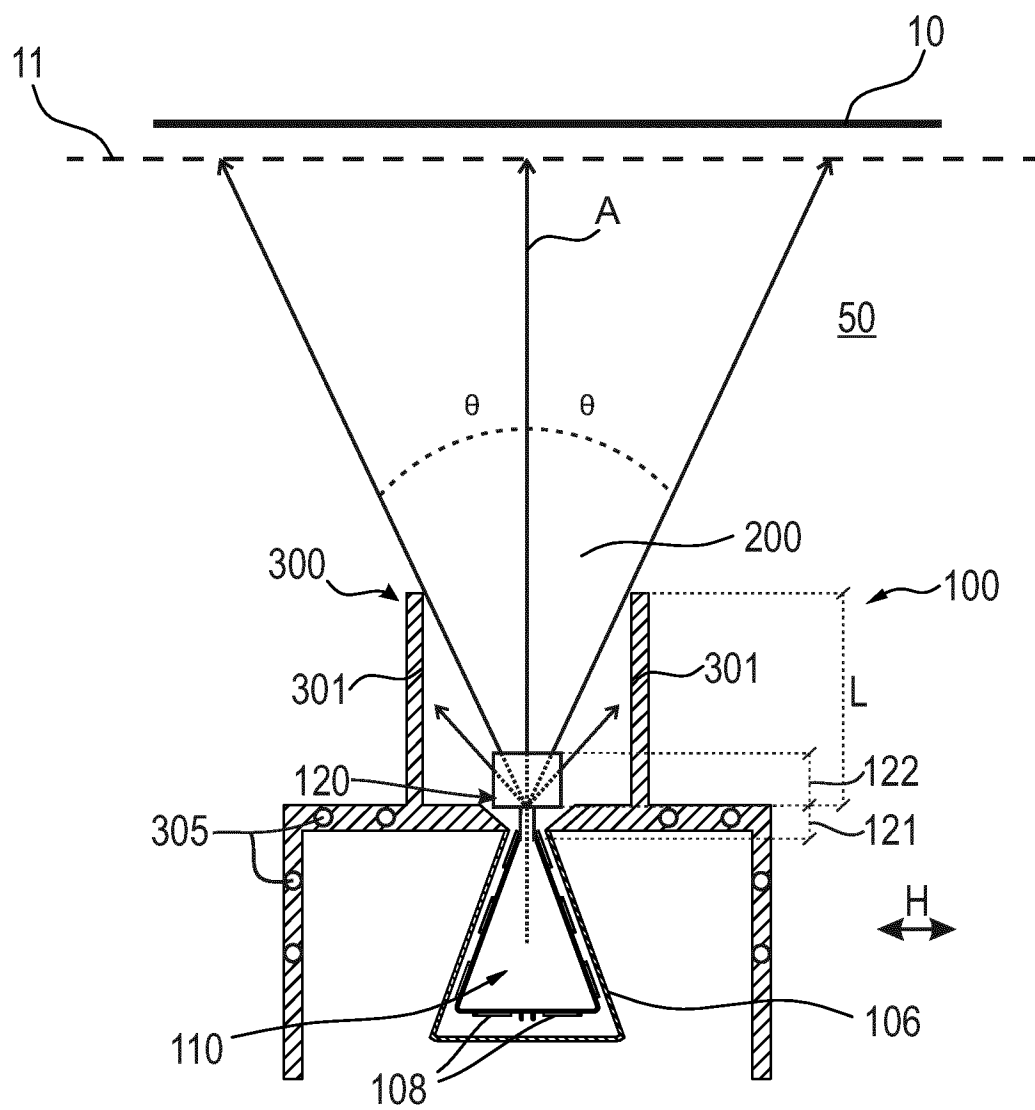


FIG. 3

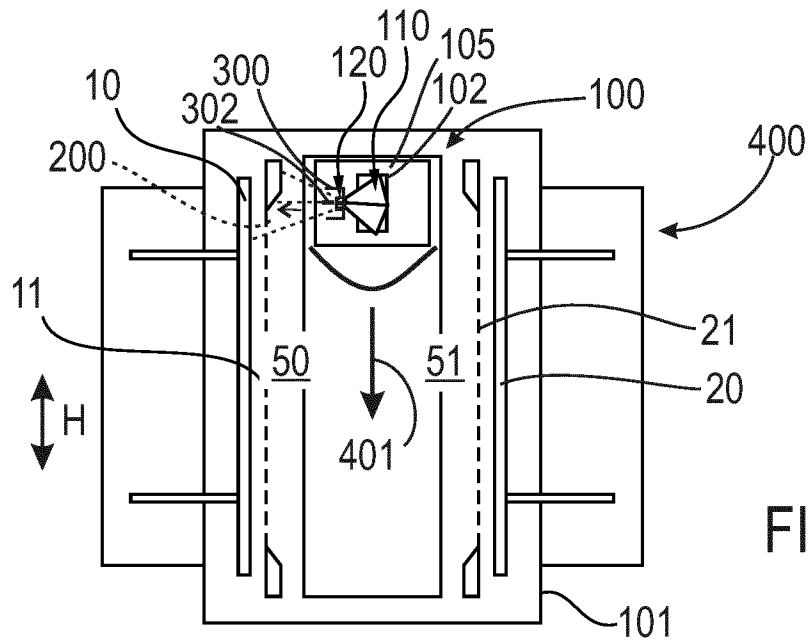


FIG. 4A

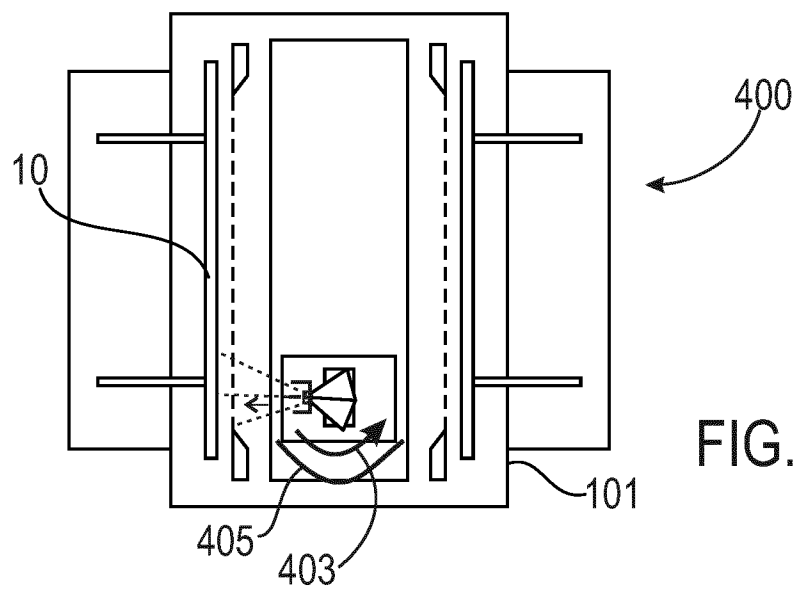


FIG. 4B

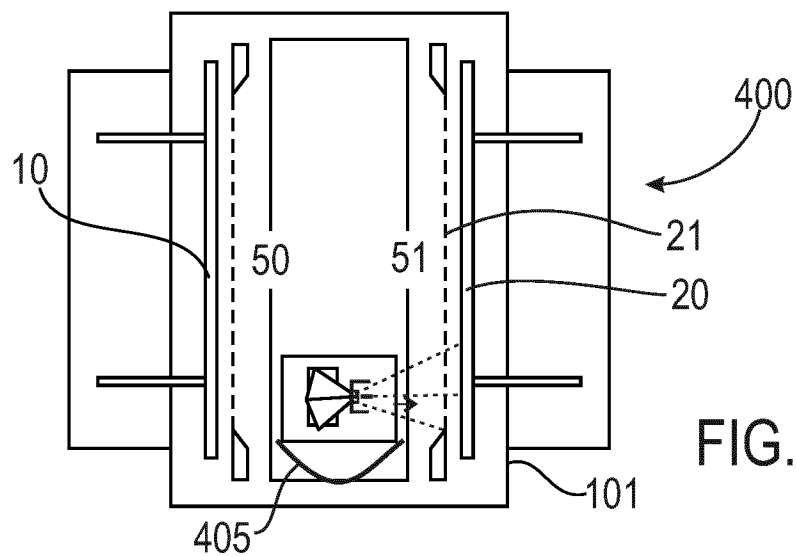


FIG. 4C

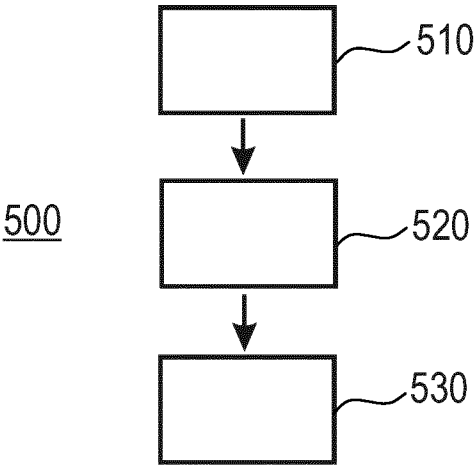


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2018/061543

A. CLASSIFICATION OF SUBJECT MATTER
 INV. C23C14/24 C23C16/455
 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	WO 2016/070942 A1 (APPLIED MATERIALS INC [US]; BANGERT STEFAN [DE]; LOPP ANDREAS [DE]; GE) 12 May 2016 (2016-05-12) paragraphs [0022] - [0032]; figures 1c,1d, 1f	1,2,6, 12,14-16
X	US 2010/189929 A1 (NEAL JAMES W [US] ET AL) 29 July 2010 (2010-07-29) paragraphs [0014] - [0028]; figures 1-3	1-7, 14-16
A	US 2012/237679 A1 (MADIGAN CONOR F [US] ET AL) 20 September 2012 (2012-09-20) paragraphs [0043] - [0045]; figure 5	1-17



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

2 November 2018

Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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