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(71) Applicant: **APPLIED MATERIALS, INC.** [US/US];
 3050 Bowers Avenue, Santa Clara, California 95054 (US).

(72) Inventors; and

(71) Applicants (*for US only*): **WHITE, John M.** [US/US];
 28530 Hayward Blvd., Hayward, California 94542 (US).
SCHNAPPENBERGER, Frank [DE/DE]; Heppenberger
 19, 63867 Johannesburg (DE). **BUSCH, John D.** [US/US];
 6486 Pfeiffer Ranch Court, San Jose, California 95120
 (US).

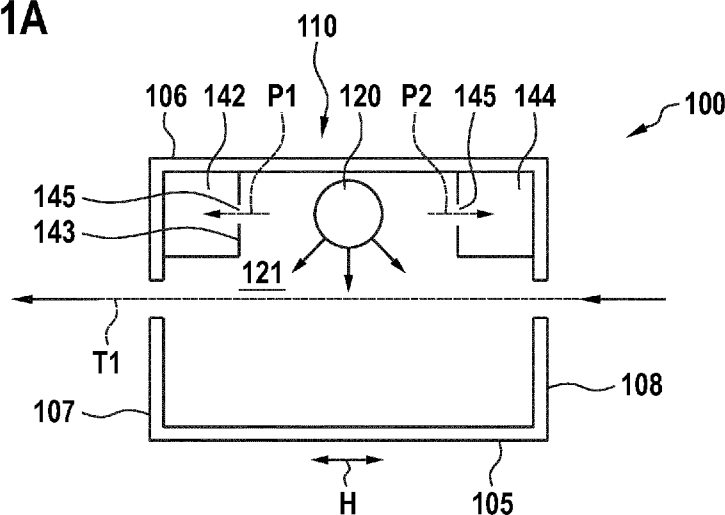
(74) Agent: **ZIMMERMANN & PARTNER PATENTAN-
 WÄLTE MBB**; Josephspitalstr. 15, 80331 München (DE).

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(54) Title: VACUUM DEPOSITION APPARATUS AND METHOD OF DEPOSITING A LAYER ON A SUBSTRATE

Fig. 1A



(57) Abstract: According to one aspect of the present disclosure, an apparatus for vacuum deposition on a substrate is provided. The apparatus comprises: a vacuum chamber (110) comprising a first side wall (112) with a first pump opening (113) and a second side wall (114) with a second pump opening (115), a first deposition area (121) configured for housing a first deposition source (120) for depositing a layer on a substrate, a first substrate transportation path (T1) along which a substrate is to be transported which extends in the vacuum chamber (110) past the first deposition area, and a first pumping channel (142) arranged adjacent to the first deposition area (121) and extending from the first pump opening (113) to the second pump opening (115), wherein the first pumping channel (142) comprises one or more lateral openings (145) defining a first gas flow path (P1) from a main volume of the vacuum chamber into the first pumping channel. Further, a deposition module as well as a method of depositing a layer on a substrate are described.

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VACUUM DEPOSITION APPARATUS AND METHOD OF DEPOSITING A LAYER ON A SUBSTRATE

TECHNICAL FIELD

5 [0001] Embodiments of the present disclosure relate to an apparatus for vacuum deposition on a substrate as well as to a deposition module for vacuum deposition on a substrate. More specifically, embodiments described herein relate to an apparatus comprising a vacuum chamber enclosing one or more deposition areas, wherein one or more thin layers can be deposited on a substrate under subatmospheric pressure in the vacuum chamber. Further embodiments relate to methods of depositing one or more layers on a substrate.

BACKGROUND

[0002] Several methods are known for depositing a material on a substrate. For instance, substrates may be coated by a physical vapor deposition (PVD) process, e.g. by sputtering, or by a chemical vapor deposition (CVD) process, e.g. by a plasma enhanced chemical vapor deposition (PECVD) process. Typically, the process is performed in a vacuum chamber in which the substrate to be coated is located during deposition. A deposition material is provided in the apparatus. A plurality of materials, but also oxides, nitrides or carbides thereof, may be used for deposition on a substrate.

20 [0003] Coated substrates may be used in several applications and in several technical fields. For instance, one application lies in the field of microelectronics, such as generating semiconductor devices. Also, substrates for displays are often coated by a PVD process or a CVD process. Further applications include insulating panels, organic light emitting diode (OLED) panels, substrates with TFT, color filters, touch panels with and without force touch feature or the like.

[0004] In particular, improvements in display manufacturing in the last years have been able to significantly reduce the manufacturing costs for mobile phones, tablet computers, television screens, and the like. Display manufacturing may be conducted on large area substrates, e.g. glass substrates, wherein typically large area substrates with a size of 1 m² or more are utilized, and layers may be deposited on one main surface or on both main surfaces of the large area substrates. Even though some aspects of semiconductor manufacturing could be successfully implemented for display manufacturing, there are some significant differences. Some of these differences are based on the much larger substrates, which result in challenges for substrate handling, moving of the substrates within the manufacturing systems and resulting particle generation, layer uniformity over the large areas, or the like.

[0005] For depositing one or more layers on a substrate under subatmospheric pressure, the vacuum chamber is typically evacuated. However, it may be difficult to provide and maintain good and uniform vacuum conditions in a deposition area of the vacuum chamber throughout the deposition process. This is particularly true when large-area substrates are to be coated, due to the large dimensions of the substrates and the vacuum chamber.

[0006] In view of the above, it would be beneficial to provide an apparatus for vacuum deposition on substrates, e.g. large area substrates, which provides good vacuum conditions and uniform gas flow conditions in a vacuum chamber with manageable effort.

SUMMARY

[0007] In light of the above, an apparatus as well as a deposition module for vacuum deposition on a substrate are provided. Further, a method of depositing a layer on a substrate is provided. Further aspects, benefits, and features of the present disclosure are apparent from the claims, the description, and the accompanying drawings.

[0008] According to one aspect of the present disclosure, an apparatus for vacuum deposition on a substrate is provided. The apparatus includes: A vacuum chamber

comprising a first side wall with a first pump opening and a second side wall with a second pump opening, a first deposition area configured for housing a first deposition source for depositing a layer on a substrate, a first substrate transportation path along which a substrate is to be transported which extends in the vacuum chamber past the first deposition area, and a first pumping channel arranged adjacent to the first deposition area and extending continuously or discontinuously from the first pump opening to the second pump opening, wherein the first pumping channel comprises one or more lateral openings defining a first gas flow path from a main volume of the vacuum chamber into the first pumping channel.

[0011] According to a further aspect of the present disclosure, a deposition module for vacuum deposition on a substrate is provided. The deposition module includes: a vacuum chamber having a first side wall with a first pump opening, at least one deposition source arranged in a first deposition area in the vacuum chamber and extending in a first direction, a first substrate transportation path along which a substrate is to be transported which extends in the vacuum chamber past the at least one deposition source, and a first pumping channel arranged adjacent to the at least one deposition source and extending from the first pump opening essentially parallel to the at least one deposition source in the first direction, wherein the first pumping channel comprises one or more lateral openings which form an opening pattern extending in the first direction and define a first gas flow path from a main volume of the vacuum chamber into the first pumping channel.

[0012] According to a further aspect of the present disclosure, a method of depositing a layer on a substrate is provided. The method includes providing a vacuum chamber having a first side wall with a first pump opening, a second side wall with a second pump opening, and a first pumping channel. The first pumping channel is arranged adjacent to a first deposition area, extends continuously or discontinuously from the first pump opening to the second pump opening, and comprises one or more lateral openings. The method further includes transporting a substrate along a first substrate transportation path through the vacuum chamber past a first deposition source arranged in the first deposition area,

and depositing a layer on a surface of the substrate, while evacuating the vacuum chamber by pumping from the first pump opening and/or from the second pump opening.

[0013] Further aspects, advantages, and features of the present disclosure are apparent from the dependent claims, the description, and the accompanying drawings.

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BRIEF DESCRIPTION OF THE DRAWINGS

[0014] So that the manner in which the above recited features of the present disclosure can be understood in detail, a more particular description of the disclosure, briefly summarized above, may be had by reference to embodiments. The accompanying drawings relate to embodiments of the disclosure and are described in the following.

10 Typical embodiments are depicted in the drawings and are detailed in the description which follows.

[0015] FIG. 1A shows a schematic sectional view of an apparatus in accordance with embodiments described herein;

[0016] FIG. 1B shows a schematic perspective view of the apparatus of FIG. 1A;

15 [0017] FIG. 2 shows a schematic sectional view of an apparatus in accordance with embodiments described herein;

[0018] FIG. 3 shows a schematic sectional view of an apparatus in accordance with embodiments described herein;

20 [0019] FIG. 4A shows a sectional view of an apparatus in accordance with embodiments described herein;

[0020] FIG. 4B shows a perspective view of the apparatus of FIG. 4A;

[0021] FIG. 5A shows a sectional view of an apparatus in accordance with embodiments described herein;

[0022] FIG. 5B shows a perspective view of the apparatus of FIG. 5A;

25 [0023] FIG. 5C shows a modification of the apparatus of FIG. 5A;

[0024] FIG. 6 shows a perspective view of an apparatus in accordance with embodiments described herein;

[0025] FIG. 7 shows a sectional view of an apparatus in accordance with embodiments described herein;

5 [0026] FIG. 8A shows a sectional view of an apparatus in accordance with embodiments described herein; FIG. 8B shows a perspective view of the apparatus of FIG. 8A;

[0027] FIG. 8C shows a modification of the apparatus of FIG. 8A in a sectional view; FIG. 8D shows a perspective view of the apparatus of FIG. 8C;

10 [0028] FIG. 9 shows a pumping channel that may be used in an apparatus according to embodiments described herein;

[0029] FIG. 10A-D show different opening patterns of a pumping channel that may be used in a deposition module according to embodiments described herein; and

[0030] FIG. 11 is a flow diagram illustrating a method according to embodiments described herein.

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DETAILED DESCRIPTION

[0031] Reference will now be made in detail to the various embodiments, one or more examples of which are illustrated in each figure. Each example is provided by way of explanation and is not meant as a limitation. For example, features illustrated or described as part of one embodiment can be used on or in conjunction with any other embodiment to yield yet a further embodiment. It is intended that the present disclosure includes such modifications and variations.

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[0032] Within the following description of the drawings, the same reference numbers refer to the same or to similar components. Generally, only the differences with respect to the individual embodiments are described. Unless specified otherwise, the description of a part or aspect in one embodiment applies to a corresponding part or aspect in another embodiment as well.

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[0033] Apparatuses for vacuum deposition on a substrate may be configured as in-line processing systems. In an in-line processing system, the substrates are moved past one or more processing tools which may be arranged in deposition areas of the vacuum chamber while the substrate is processed. The processing uniformity can be improved by a processing tool extending mainly in a first direction, while the substrate movement is in a second, different direction. These in-line processing systems have the advantage that for obtaining a high processing uniformity, for example a good layer uniformity, the substrate may be moved at a constant speed past the processing tool, in order to keep the processing properties stable. Accordingly, a good uniformity can be provided in the transport direction of the substrate (also referred to herein as “second direction”) and efforts to improve the overall uniformity may focus on the direction perpendicular to the transport direction, which may be the extension direction of the deposition sources (also referred to herein as “first direction”). Further, these in-line systems have the advantage that a large area substrate can be processed without providing an array of tools. Accordingly, costs can be reduced.

[0034] Apparatuses according to embodiments described herein may relate to such in-line processing systems. A vacuum chamber of the apparatus may include a first deposition area configured for housing a first deposition source for depositing a layer on the substrate. Further, a first substrate transportation path along which a substrate is to be transported may be provided in the vacuum chamber. The substrate transportation path may extend past the first deposition area, e.g. in the second direction. Accordingly, during operation of the apparatus, the substrate may be transported along the substrate transportation path past the first deposition area while being processed, particularly while being coated with one or more layers.

[0035] Generally, the deposition area as well as the deposition source which may be arranged in the deposition area may extend in a first direction (V), for example in a vertical direction. The substrate transportation path may extend in a second, different direction. The second direction may be essentially perpendicular to the first direction. For example, the second direction of the substrate transportation path may be a horizontal

direction. Accordingly, when transported past the deposition area along the substrate transportation path, e.g. at a constant transport speed, the substrate may be uniformly coated in the horizontal direction.

[0009] For some applications, it may be sufficient to coat only one main surface of a substrate with one or more layers, e.g. to provide a multilayer stack on a front side of the substrate. For some applications, both main surfaces of substrates may be processed, e.g. coated with one layer or with a stack of layers.

[0036] FIG. 1A is a schematic sectional view of an apparatus 100 for vacuum deposition on a substrate according to embodiments described herein. FIG. 1B is a schematic perspective view of the apparatus 100 of FIG. 1A. The apparatus 100 includes a vacuum chamber 110 which may be evacuated to a subatmospheric pressure, e.g. to a pressure of 10 mbar or below, particularly 1 mbar or below.

[0037] The apparatus 100 includes a first deposition area 121 in the vacuum chamber 110 which is configured for housing a first deposition source 120 for depositing a layer on the substrate. Further, the apparatus 100 includes a first substrate transportation path T1 along which a substrate may be transported during operation of the apparatus. The first substrate transportation path T1 extends in the vacuum chamber past the first deposition area 121. When the first deposition source 120 is housed in the first deposition area 121, the substrate transportation path extends past the first deposition source 120.

[0038] Accordingly, a substrate may be guided along the first substrate transportation T1 past the first deposition source 120, which is arranged in the first deposition area 121, while a layer is deposited on a main surface of the substrate by the first deposition source 120.

[0039] In some embodiments, the first deposition source 120 may extend in a first direction (V), e.g. in an essentially vertical direction, and the substrate transportation path T1 may extend in a second direction (H), e.g. in an essentially horizontal direction. The substrate may be arranged in an essentially vertical orientation, while being transported

past the first deposition source 120 in a horizontal transport direction, e.g. at a constant speed. A uniform layer can be deposited on a main surface of the substrate.

[0040] The vacuum chamber 110 may have a plurality of outer side walls which separate an inner volume of the vacuum chamber 110 from the outer environment which may be provided at an atmospheric pressure. In particular, the vacuum chamber may have a first side wall 112 and a second side wall 114. The first side wall 112 and the second side wall 114 may be opposite side walls of the vacuum chamber 110 in some embodiments.

[0041] In the embodiment shown in FIG. 1B, the first side wall 112 is a top wall of the vacuum chamber 110, and the second side wall 114 is a bottom wall of the vacuum chamber 110. As will be apparent to the skilled person, the first side wall and the second side wall may alternatively be lateral side walls of the vacuum chamber, e.g. a front side wall 105, a rear side wall 106, a left side wall 107, or a right side wall 108.

[0042] The first side wall 112 includes a first pump opening 113 and the second side wall 114 includes a second pump opening 115.

[0043] According to some embodiments described herein, a first pumping channel 142 may extend from the first pump opening 113 to the second pump opening 115 and may be arranged adjacent to the first deposition area 121. The first pumping channel 142 includes one or more lateral openings 145 defining a first gas flow path P1 from a main volume of the vacuum chamber 110 into the first pumping channel 142.

[0044] In other words, the first pumping channel 142 may extend through an inner volume of the vacuum chamber 110 from the first side wall 112, e.g. from the top wall, to the second side wall 114, e.g. to the bottom wall. The first side wall 112 may be opposite to the second side wall 114. In this case, the first pumping channel 142 may extend through the vacuum chamber 110 from a first side of the vacuum chamber to an opposite second side of the vacuum chamber. Since the first pump opening 113 is provided in the first side wall 112 and the second pump opening 115 is provided in the second side wall 114, the first pumping channel 142 can be evacuated by pumping from the first pump opening 113 and/or or by pumping from the second pump opening 115. In other words,

the first pumping channel 142 may be evacuated by pumping from either side or from both sides of the first pumping channel 142.

[0045] In some embodiments, the first pumping channel 142 may extend continuously from the first pump opening 113 to the second pump opening 115. In other words, the first pumping channel 142 may extend through the vacuum chamber 110 without any interruption or break. For example, a channel wall of the first pumping channel 142 may provide a continuous material connection from the first side wall 112 of the vacuum chamber 110 through to the second side wall 114 of the vacuum chamber. The channel wall of the first pumping channel 142 may be connected to the first side wall 112 at a first end of the first pumping channel and to the second side wall 114 at a second end of the first pumping channel.

[0046] In some embodiments, the first pumping channel 142 may provide a continuous fluid connection through the vacuum chamber 110 from the first pump opening 113 to the second pump opening 115. The inner clearance of the first pumping channel 142 may be constant or may be varying at least partially between the first pump opening 113 and the second pump opening 115. Accordingly, the first pumping channel 142 can be evacuated or pumped without blocking or hindering the gas flow between the first pump opening 113 and the second pump opening 115. The gas to be pumped from a main volume of the vacuum chamber may enter the first pumping channel via the one or more lateral openings 145 of the first pumping channel 142.

[0047] In other embodiments, the first pumping channel 142 may extend discontinuously from the first pump opening 113 to the second pump opening 115. In other words, the first pumping channel 142 may have at least one break or interruption between the first side wall 112 and the second side wall 114. For example, the first pumping channel may not provide a continuous material connection between the first side wall 112 and the second side wall 114. For example, the first pumping channel 142 may have one or more gaps which may extend over 5 cm or less, particularly 2 cm or less. Pumping the first pumping channel 142 from either side or from both sides may still be possible, even if one or more discontinuities are provided in the first pumping channel 142.

[0048] In some embodiments, the first pumping channel 142 may not provide a continuous fluid connection through the vacuum chamber 110 from the first pump opening 113 to the second pump opening 115. For example, a first compartment of the first pumping channel 142 may be configured to be (predominantly) pumped from the first pump opening 113, and a second compartment of the first pumping channel 142 may be configured to be (predominantly) pumped from the second pump opening 115. For example, the inner clearance of the first pumping channel 142 may vary from a first sectional area to a second sectional area which may be smaller than the first sectional area, e.g. less than 50%. The gas flow within the first pumping channel may be adjusted by providing the first pumping channel with a varying clearance and/or with discontinuities.

[0049] In the embodiment shown in FIG. 1B, the first pumping channel 142 extends along an essentially straight line, i.e. essentially linearly, from the first pump opening 113 to the second pump opening 115. The first pump opening 113 may be provided at a first position in the first side wall 112 which may correspond to a second position in the second side wall 114 where the second pump opening 115 may be provided. In other words, the first pump opening 113 and the second pump opening 115 may be provided at opposite positions of the vacuum chamber 110. Pumping efficiency can be improved.

[0050] In the embodiment shown in FIG. 1B, the first pumping channel 142 extends continuously and linearly through the vacuum chamber in a top-bottom direction, i.e. in a direction from the top wall of the vacuum chamber toward the bottom wall of the vacuum chamber.

[0051] In some embodiments, the first pumping channel 142 is arranged adjacent to the first deposition area 121, particularly directly adjacent to the first deposition area 121. For example, when the first deposition source 120 is provided in the first deposition area 121, a minimum distance between the first deposition source 120 and the first pumping channel 142 may be 50 cm or less, particularly 30 cm or less.

[0052] In some embodiments, the first pumping channel 142 may be at least partially curved. Alternatively or additionally, the first pumping channel 142 may at least partially extend in steps between the first pump opening 113 and the second pump opening 115. In some embodiments, the first pumping channel may extend between two side walls of the vacuum chamber which are not opposite side walls. In this case, the first pumping channel may extend at least partially along a curved line or may be provided with an angled section.

[0053] Typically, it is beneficial to maintain a uniform process gas flow distribution in the first deposition area 121 of the vacuum chamber, which may be difficult to achieve in the case of an apparatus configured to coat large-area substrates. According to the embodiments described herein, the gas distribution as well as the vacuum conditions are improved by specific configurations of the first pumping channel 142 which is provided in the vacuum chamber 110. The process gas which may enter the first deposition area 121 via a gas inlet of the deposition source may flow along the first gas flow path P1 from the main volume of the vacuum chamber through the one or more lateral openings 145 provided in the first pumping channel 142 into the inner volume of the first pumping channel 142. The first pumping channel 142 may be pumped from one side or from both sides, i.e. by pumping with a first vacuum pump from the first pump opening 113 and/or by pumping with a second vacuum pump from the second pump opening 115. Accordingly, the first pumping channel 142 may be pumped quickly, effectively and uniformly.

[0054] The one or more lateral openings 145 may be arranged in any of the channel walls of the first pumping channel 142. For example, one or more openings may be provided in a channel wall 143 of the first pumping channel 142 which is directed toward the first deposition area 121, and/or one or more openings may be provided in a channel wall of the first pumping channel which is directed toward the first substrate transportation path T1. In some embodiments, at least one lateral opening is provided in a channel wall 143 which is directed toward the first deposition source 120.

[0055] In the embodiment depicted in FIG. 1B at least one slit-like lateral opening is provided in the first pumping channel 142. The length direction of the slit-like opening(s) may be parallel to the length direction of the first deposition source 120, particularly parallel to the first direction (V).

5 [0056] The one or more lateral openings 145 in the channel wall 143 of the first pumping channel 142 define a first gas flow path P1 from a main volume of the vacuum chamber 110 into the first pumping channel 142. The main volume of the vacuum chamber may be understood as a processing compartment of the vacuum chamber, where the first deposition area 121 and the first substrate transportation path T1 are arranged. For
10 example, during processing, the first deposition source 120 and the substrate may be located in the main volume of the vacuum chamber. The first pumping channel 142 may be a pumping compartment which may be separated from the main volume of the vacuum chamber by the channel walls of the first pumping channel 142. The channel walls of the first pumping channel 142 may be at least partially configured as an inner partition wall of
15 the vacuum chamber.

[0057] The inner volume of the first pumping channel 142 may be in fluid communication with the main volume of the vacuum chamber via the one or more lateral openings 145 which are provided in at least one channel wall of the first pumping channel 142.

20 [0058] In some embodiments, the first pumping channel 142 includes a plurality of lateral openings, e.g. two or more, five or more, or ten or more lateral openings. In some embodiments, the first pumping channel may include a single lateral opening which may be shaped as a slit opening. In yet further embodiments, two or more slit-like lateral openings may be provided in at least one or more channel walls of the first pumping
25 channel 142. By arranging the openings in a predefined pattern and shape, the gas flow and the vacuum conditions in the vacuum chamber can be adjusted and improved.

[0059] In some embodiments, which may be combined with other embodiments described herein, the one or more lateral openings 145 form an opening pattern extending

in the length direction of the first pumping channel 142, e.g. in the first direction (V) which may be the vertical direction in some embodiments. In some embodiments, also the first deposition source 120 may extend in the first direction (V). Accordingly, the process gas may be sucked into the first pumping channel 142 through the one or more lateral openings 145 of the opening pattern along the length extension of the first deposition source 120. More uniform pumping conditions can be provided, even when using a long deposition source configured for coating large area substrate, e.g. a deposition source having a length of 1 m or more in the first direction (V).

[0060] The opening pattern may include a single opening provided in the first pumping channel 142 or several spaced-apart openings provided with a respective distance therebetween. The diameter or the width of the opening(s) and/or the distance between adjacent openings may be constant in the length direction of the first pumping channel 142. In some embodiments, the opening shape and/or distance vary along the length direction of the first pumping channel 142. Uniform pumping conditions may also be provided in a center area of the vacuum chamber 110 which is distant from the first side wall and from the second side wall by varying the opening pattern, as will be explained in more detail further below.

[0061] It is noted that, in some embodiments described herein, the first pumping channel may not extend between a first pump opening and a second pump opening. Rather, according to some embodiments described herein, the pumping uniformity may be improved by providing a first pumping channel which is arranged adjacent to at least one deposition source and extends essentially parallel to the at least one deposition source in a first direction (V), e.g. in the vertical direction. The pumping channel includes one or more lateral openings 145 which form an opening pattern extending in the first direction (V) and define a first gas flow path P1 from a main volume of the vacuum chamber into the first pumping channel. The pumping channel may be in fluid communication with only one pump opening provided in one of the side walls of the vacuum chamber 110, e.g. in the top side wall, in the bottom side wall, or in one of the lateral side walls.

Accordingly, in some embodiments, the first pumping channel is evacuated from a single pump opening only.

[0062] In some embodiments, which may be combined with other embodiments described herein, (i) the at least one deposition source, (ii) the first pumping channel as well as (iii) the opening pattern may extend in the first direction (V), which may be the vertical direction in some embodiments. Accordingly, the pumping uniformity in the first direction (V) may be improved along the length direction of the at least one deposition source. This is because the first gas flow path P1 may run from the main volume of the vacuum chamber through the opening pattern into the interior of the pumping channel, wherein both the first pumping channel and the opening pattern may be adapted to the orientation of the deposition source. In particular, the opening pattern may extend parallel to and in line with the first pumping channel in a channel wall of the first pumping channel.

[0063] For example, in some embodiments, the first pumping channel may only extend through a portion of the vacuum chamber, e.g. in a top-bottom direction or in a lateral direction. For example, the first pumping channel may have a channel length which may correspond to between 40% and 90% of the outer dimension of the vacuum chamber, e.g. in the first direction (V). For example, the first pumping channel may have a channel length of 50 cm or more and 2 m or less in some embodiments.

[0064] As will be apparent to the skilled person, a pumping channel which is in fluid communication with a single pump opening in one side wall of the vacuum chamber may exhibit any of the features described herein with respect to a pumping channel which is in fluid communication with two pump openings in two different side walls. For example, details of the channel cross section and/or of the one or more lateral openings provided in the channel wall may correspond to the respective details of other embodiments described herein.

[0065] In yet further embodiments, the first pumping channel may be in fluid communication with more than two pump openings, e.g. with three, four or more pump openings which may be provided in two or more side walls of the vacuum chamber.

[0066] Embodiments described herein may include one or more deposition sources for coating movable substrates, e.g. for depositing one or several thin films on the substrate. Deposition sources may be configured as CVD deposition sources for coating a substrate by chemical vapor deposition, e.g. as PECVD and/or HWCVD deposition sources, or deposition sources may be configured as PVD deposition sources for coating a substrate by physical vapor deposition, e.g. as sputter deposition sources.

[0067] Substrates used in some embodiments described herein may be inflexible substrates, e.g., a wafer, slices of transparent crystal such as sapphire or the like, or a glass plate. However, the present disclosure is not limited thereto and the term substrate may also embrace flexible substrates such as a web or a foil.

[0068] Specifically, a “large area substrate” may be used for display manufacturing and be a glass or plastic substrate. For example, substrates described herein shall embrace substrates which are typically used for an LCD (Liquid Crystal Display), a PDP (Plasma Display Panel), and the like. A large area substrate may have a main surface area of 0.5 m² or more to be coated, particularly 1 m² or more. For instance, a large area substrate can be GEN 4.5, which corresponds to about 0.67 m² substrates (0.73 x 0.92m), GEN 5, which corresponds to about 1.4 m² substrates (1.1 m x 1.3 m), or larger. A large area substrate can further be GEN 7.5, which corresponds to about 4.29 m² substrates (1.95 m x 2.2 m), GEN 8.5, which corresponds to about 5.7m² substrates (2.2 m x 2.5 m), or even GEN 10, which corresponds to about 8.7 m² substrates (2.85 m × 3.05 m). Even larger generations such as GEN 11 and GEN 12 and corresponding substrate areas can similarly be implemented.

[0069] For coating large-area substrates, the vacuum chamber 110 of some embodiments described herein may have an outer dimension in the first direction (V) of 1 m or more, particularly 2 m or more, more particularly 3 m or more. The channel length of the first

pumping channel in the first direction may essentially correspond to the outer dimension of the vacuum chamber and may be 1 m or more, particularly 2 m or more. The length of the first deposition source 120 in the first direction (V) may be 1 m or more, particularly 2 m or more. The substrate can be transported through the vacuum chamber 110 in a vertical orientation, while essentially the full height of the substrate can be coated by the first deposition source 120.

[0070] According to some embodiments, which can be combined with other embodiments described therein, the substrate may be in a vertical orientation during processing, for example, during a deposition or coating process and/or during transport of the substrate through the vacuum chamber and past the first deposition area. As used throughout the present disclosure, “vertical” or “substantially vertical” is understood particularly when referring to the substrate orientation, and allows for a deviation from the vertical direction or orientation of $\pm 20^\circ$ or below, e.g. of $\pm 10^\circ$ or below. This deviation can be provided for example because a substrate carrier with some deviation from the vertical orientation might result in a more stable substrate position or a facing down substrate orientation might even better reduce particles on the substrate during deposition. Yet, the substrate orientation, e.g., during a layer deposition process, is considered substantially vertical, which is considered different from the horizontal substrate orientation.

[0071] Specifically, as used throughout the present disclosure, terms like “vertical direction” or “vertical orientation” are understood to distinguish over “horizontal direction” or “horizontal orientation”. The vertical direction can be substantially parallel to the force of gravity.

[0072] The substrates of the present disclosure may be supported by a substrate carrier during processing and transport, e.g., during layer deposition and/or transport of the substrate in the vacuum chamber. It is noted that the terms “substrate carrier”, “carrier” and “substrate support” can be used synonymously.

[0073] According to embodiments of the present disclosure, the apparatus 100 can use one or more transport devices for holding and transporting the carriers together with the substrates along the first substrate transportation path T1. In some implementations, the transport device may be provided as a magnetic levitation system for holding the carriers in a suspended state. Optionally, a magnetic drive system configured for moving or conveying the carriers along the first substrate transportation path T1 in a transport direction may be used. The magnetic drive system can be included in the magnetic levitation system or can be provided as a separate entity.

[0074] In some implementations, a mechanical transport system may be provided. The transport system may include rollers for transporting the carriers along the first substrate transportation path T1, wherein a drive for rotating the rollers may be provided. Mechanical transport systems may be easy to implement and robust, durable and maintenance friendly.

[0075] PVD sputter systems were developed to coat thin substrates, e.g. thin glass substrates, e.g. for display applications, in a vacuum chamber. In typical deposition apparatus, each substrate may be held by a carrier, and the carriers may be transported through the vacuum chamber by respective transport devices. The carriers may be moved by the transport devices such that first main surfaces of the substrates are exposed to the first deposition source 120 which may be arranged in the first deposition area 121. The first main surfaces of the substrates may be processed, e.g. coated with a thin coating layer, while the substrates are transported by the transport devices past the first deposition source 120 at a predetermined speed.

[0076] In some embodiments, which may be combined with other embodiments described herein, the first pump opening 113 is provided in a top wall of the vacuum chamber 110, the second pump opening 115 is provided in a bottom wall of the vacuum chamber 110, and the first pumping channel 142 extends through the vacuum chamber 110 in a top-bottom direction. Therein, the first pumping channel 142 may extend

continuously and/or along a straight line from the first pump opening 113 to the second pump opening 115.

[0077] In some embodiments, which may be combined with other embodiments described herein, one or more lateral openings 145 of the first pumping channel 142 may be directed towards the first deposition area 121, respectively. In the embodiment depicted in FIG. 1B, the slit-like openings provided in the channel wall 143 of the first pumping channel 142 are directed toward the first deposition source 120 which is arranged in the first deposition area 121. Pumping efficiency can be increased, as the gas density is typically high in the first deposition area 121, where the processing gas is typically injected by a gas inlet, e.g. by a gas lance, of the first deposition source 120.

[0078] In some embodiments, which may be combined with other embodiments described herein, the one or more lateral openings 145 form an opening pattern extending in a length direction of the first pumping channel 142, e.g. in a vertical direction.

[0079] In some embodiments, which may be combined with other embodiments described herein, the first pumping channel 142 may be provided as an inner support wall of the vacuum chamber 110 extending from the first side wall 112 to the second side wall 114. In particular, in some embodiments, the first pumping channel 142 may be configured as a structural element of the vacuum chamber 110 which may strengthen and support the vacuum chamber. The stability of the vacuum chamber 110 can be improved.

[0080] Under vacuum, the atmospheric pressure on the side walls of the vacuum chamber 110 can be very high, especially for apparatuses configured for coating large-area substrates. Using the first pumping channel 142 as a structural element as well as a pumping compartment can achieve improved pumping characteristics while also helping to reduce the overall material content of the vacuum chamber. In particular, the strength and stability of the vacuum chamber 110 can be improved by the at least one pumping channel or by providing a plurality of pumping channels with least additional amount of material.

[0081] For example, a first end of the first pumping channel can be connected to, particularly fixed to, the first side wall 112 of the vacuum chamber, and/or a second opposite end of the first pumping channel can be connected to, particularly fixed to, the second side wall 114 of the vacuum chamber 110. The stability of the vacuum chamber can be increased.

[0082] In some embodiments, which may be combined with other embodiments described herein, the channel wall of the first pumping channel 142 may have a round or essentially rectangular sectional shape in a sectional plane perpendicular to the length direction of the first pumping channel. A rectangular pumping channel provides a particularly large inner clearance and thus allows a good pumping efficiency. A round pumping channel may provide a particularly stable support of the vacuum chamber with a reduced amount of material.

[0083] A thickness of the channel wall may be 1 mm or more, particularly 3 mm or more, more particularly 5 mm or more in some embodiments, and/or the channel wall may be made of a stable material, e.g. metal, particularly steel.

[0084] In some embodiments, which may be combined with other embodiments described herein, the first pumping channel 142 may have an inner sectional area of 100 cm² or more and 5000 cm² or less, particularly 400 cm² or more and 2000 cm² or less, more particularly 800 cm² or more and 1000 cm² or less. By providing a large sectional area of the first pumping channel, the pumping efficiency can be improved. In some embodiments, further pumping channels may have the same sectional area.

[0085] In some embodiments, which may be combined with other embodiments described herein, a first vacuum pump may be connected to the first pump opening 113 and configured to evacuate the first pumping channel 142 from a first side. Alternatively or additionally, a second vacuum pump may be connected to the second pump opening 115 and configured to evacuate the first pumping channel 142 from a second side. The first vacuum pump and/or the second vacuum pump may be configured as turbomolecular

pumps which may be directly connected to the first side wall 112 and/or to the second side wall 114 of the vacuum chamber, where the first pump opening 113 and the second pump opening 115 are provided.

[0086] In some embodiments, a vacuum pump may be connected to only one of the first pump opening 113 and the second pump opening 115, and the respective other opening may be closed, e.g. via a lid, particularly via a blind flange. In some embodiments, no vacuum pump may be connected to the first pump opening 113 and the second pump opening 115. For example, both the first pump opening and the second pump opening may be closed, e.g. via a lid, particularly via a respective blind flange. In particular, it may not always be reasonable or necessary to pump the first pumping channel from both sides, e.g. when no high gas loads are injected in an area of the main volume adjacent to the first pumping channel.

[0087] In some embodiments, which may be combined with other embodiments described herein, a first deposition source 120 may be arranged in the first deposition area 121 and/or may extend essentially parallel to and in line with the first pumping channel 142.

[0088] In some embodiments, which may be combined with other embodiments described herein, the apparatus 100 may include more than one pumping channel. For example, the first pumping channel 142 and a second pumping channel 144 and optionally further pumping channels may be provided in the vacuum chamber 110.

[0089] The second pumping channel 144 may extend essentially parallel to the first pumping channel 142, particularly in the first direction (V), e.g. in a vertical direction.

[0090] In some embodiments, the second pumping channel 144 may be arranged adjacent to the first deposition area 121 on the opposite side with respect to the first pumping channel 142. For example, in the embodiment depicted in FIG. 1A and FIG. 1B, the first pumping channel 142 is arranged on a first side of the first deposition area 121, and the second pumping channel 144 is arranged on a second side of the first deposition area 121

opposite to the first side. Accordingly, the process gas can be evacuated more quickly and more uniformly from the first deposition area 121.

[0091] In particular, the first deposition area 121 may be located between the first pumping channel 142 and the second pumping channel 144 in some embodiments. The first deposition source 120 may be arranged in a center section between the first pumping channel 142 and the second pumping channel 144.

[0092] In some embodiments, the second pumping channel 144 may extend through the vacuum chamber 110 from a second channel-first pump opening 116 in the first side wall 112 to a second channel-second pump opening 117 in the second side wall 114. The second channel-first pump opening 116 may be provided in the top wall of the vacuum chamber, and the second channel-second pump opening 117 may be provided in the bottom wall of the vacuum chamber. Accordingly, the second pumping channel 144 may extend through the vacuum chamber in a top-bottom direction, particularly continuously and/or along a straight line from the second channel-first pump opening 116 to the second channel-second pump opening 117. The second pumping channel 144 may extend parallel with respect to the first pumping channel 142, e.g. with a distance of 20 cm or more and 1 m or less therebetween.

[0093] In other embodiments, the second pumping channel and the first pumping channel are not parallel with respect to each other. In yet further embodiments, the second pumping channel may extend essentially parallel to the deposition source in the first direction (V). The second pumping channel does not necessarily extend between two pump openings. In particular, in some embodiments, the second pumping channel may be configured to be pumped from a single pump opening which is provided in one of the side walls of the vacuum chamber, e.g. in the top wall, in the bottom wall or in one of the lateral side walls.

[0094] It is further noted that the second pumping channel is not necessarily arranged on an opposite side of the first deposition area with respect to the first pumping channel. For

example, both the first pumping channel and the second pumping channel may be arranged on the same side of the first deposition area 121, and optionally on opposite sides of the first substrate transportation path T1. Other arrangements of the first pumping channel and the second pumping channel are possible and will be apparent to the skilled person. In particular, the second pumping channel may be arranged such that more uniform pumping conditions and a more uniform process gas distribution can be provided in the vacuum chamber, particularly in the first deposition area 121.

[0095] Similar to the first pumping channel 142, the second pumping channel 144 may include one or more lateral openings 145 defining a second gas flow path P2 from the main volume of the vacuum chamber 110 into the second pumping channel 144.

[0096] As will be apparent to the skilled person, the second pumping channel 144 may have some or all of the features described above with reference to the first pumping channels 142. In order to avoid repetitions, these features are not repeated here.

[0097] FIG. 2 shows an apparatus 200 for vacuum deposition on a substrate in a schematic sectional view. The apparatus 200 may be similar to the apparatus 100 shown in FIG. 1A, and corresponding features are not repeated here.

[0098] The apparatus 200 includes a vacuum chamber 110, a first deposition area 121 for housing a first deposition source 120 for depositing a layer on a substrate, a first substrate transportation path T1 along which a substrate is to be transported which extends in the vacuum chamber past the first deposition area 121, and a first pumping channel 142.

[0099] The first deposition area 121 may be located on a first side of the first substrate transportation path T1, e.g. on a front side. Further, a second deposition area 122 configured to house a second deposition source 124 may be located on a second side of the first substrate transportation path T1, particularly on an opposite side, e.g. on the rear side. In particular, in some embodiments, the first deposition area 121 and the second deposition area 122 may be located on opposite sides of the first substrate transportation path T1.

[00100] Two-side processing of the substrate may be possible by coating a substrate which is transported along the first substrate transportation path T1 with the first deposition source 120 and with the second deposition source 124. Both main surfaces of the substrate may be coated with one or more thin layers. During processing, the substrate may be held in a substrate carrier, which allows for two-side processing of the substrate. In some embodiments, the substrate is held and transported in a vertical orientation along the first substrate transportation path.

[00101] In the embodiment shown in FIG. 2, a total of four pumping channels are provided. Alternatively, only two, three, or more than four pumping channels may be provided. Each pumping channel may extend essentially parallel to the first deposition source 120 and/or to the second deposition source 124, particularly in the first direction (V). Further, one or more lateral openings 145 defining a respective gas flow path from the main volume of the vacuum chamber into the respective pumping channel may be provided in each of the pumping channels.

[00102] In some embodiments, the first pumping channel 142 may be provided on a first lateral side of the first deposition area 121, the second pumping channel 144 may be provided on a second lateral side of the first deposition area 121 opposite to the first lateral side, a third pumping channel 146 may be provided on a first lateral side of the second deposition area 122, and a fourth pumping channel 148 may be arranged on a second lateral side of the second deposition area 122 opposite to the first lateral side. Alternatively or additionally, the first pumping channel 142 and the second pumping channel 144 may be arranged on a first side of the first substrate transportation path T1, and the third pumping channel 146 and the fourth pumping channel 148 may be arranged on a second side of the first substrate transportation path opposite to the first side.

[00103] In some embodiments, which may be combined with other embodiments described herein, the third pumping channel 146 may extend through the vacuum chamber from a third channel-first opening provided in the first side wall 112 of the vacuum chamber to a third channel-second opening provided in the second side wall 114 of the

vacuum chamber, and/or the fourth pumping channel 148 may extend through the vacuum chamber from a fourth channel-first opening provided in the first side wall 112 of the vacuum chamber to a fourth channel-second opening provided in the second side wall 114 of the vacuum chamber. In particular, the pumping channels may extend essentially parallel to each other, particularly in the first direction (V), e.g. in the vertical direction. Pumping uniformity can be improved.

[00104] Each pumping channel, particularly the second pumping channel 144, the third pumping channel 146 and/or the fourth pumping channel 148 may have some features or all the features described above with respect to the first pumping channel 142.

[00105] The apparatus 200 may further include a first transport device, particularly a magnetic levitation system or a roller system, configured for transporting a substrate along the first substrate transportation path T1, e.g. between the first deposition area 121 and the second deposition area 122. The transport device may be configured for changing the movement direction of the substrate in the vacuum chamber 110. For example, after coating, the transport direction of the substrate may be inverted, and the substrate may be transported out of the vacuum chamber in an opposite direction. In some embodiments, the substrate may enter the vacuum chamber through a substrate entrance opening in a first lateral side wall, may be transported through the vacuum chamber while being coated, and may exit the vacuum chamber through a substrate exit opening in a second lateral side wall opposite to the first lateral side wall.

[00106] FIG. 3 shows an apparatus 300 for vacuum deposition on a substrate in a schematic sectional view. The apparatus 300 may be similar to the apparatus 100 shown in FIG. 1A and FIG. 1B, and corresponding features are not repeated here.

[00107] The apparatus 300 includes a vacuum chamber 110, a first deposition area 121 for housing a first deposition source 120 for depositing a layer on a substrate, a first substrate transportation path T1 along which a substrate is to be transported which extends in the vacuum chamber past the first deposition area 121, and a first pumping

channel 142. Optionally, further pumping channels may be provided, e.g. a second pumping channel 144.

[00108] In some embodiments, the first substrate transportation path T1 may be located on a first side of the first deposition area 121, e.g. on a front side of the first deposition area 121, and a second substrate transportation path T2 along which a further substrate is to be transported may extend in the vacuum chamber 110 past the first deposition area 121 on a second side of the first deposition area, e.g. on a rear side of the first deposition area. The first substrate transportation path T1 and the second substrate transportation path T2 may be located on opposite sides of the first deposition area 121. In some embodiments, the first substrate transportation path T1 and the second substrate transportation path T2 may be at least partially parallel to each other.

[00109] During operation of the apparatus 300, a first substrate may be transported along the first substrate transportation path T1, while being coated by the first deposition source 120 which may be arranged in the first deposition area 121 or by another deposition source. A second substrate may be transported along the second substrate transportation path T2, while being coated by the first deposition source 120 or by another deposition source simultaneously or subsequently. The throughput of the apparatus can be increased. In yet further embodiments, a transport system may be configured to transport a single substrate along the first substrate transportation path T1 and then along the second substrate transportation path T2, or vice versa. Multiple layers may be deposited on the substrate.

[00110] In some embodiments, which may be combined with other embodiments described herein, the first deposition source may be a bi-directional deposition source 123 which may be configured to deposit material toward the first substrate transportation path T1 and toward the second substrate transportation path T2. For example, the bi-directional deposition source 123 may be a bi-directional sputter device.

[00111] The apparatus may further include a first transport device, particularly a magnetic levitation system or a roller system, configured for transporting a substrate along the first substrate transportation path T1, and/or a second transport device, particularly a magnetic levitation system or a roller system, configured for transporting a substrate along the second substrate transportation path T2.

[00112] In some embodiments, a path switching module may be provided for transferring a substrate from the first substrate transportation path T1 to the second substrate transportation path T2 or vice versa.

[00113] The first pumping channel 142 may be arranged adjacent to the first deposition area 121 and may extend in a first direction which may be essentially perpendicular to the transport direction of the substrate past the first deposition area. For example, the first pumping channel 142 may extend at least partially in a vertical direction, and the first substrate transportation path T1 and the second substrate transportation path T2 may extend in a horizontal direction.

[00114] The first pumping channel 142 may include a channel wall with one or more lateral openings which form an opening pattern which defines a first gas flow path from a main volume of the vacuum chamber through the one or more lateral openings 145 into the interior of the first pumping channel 142. The first pumping channel 142 may be evacuated from one side or from both sides thereof.

[00115] A second pumping channel 144 may be arranged on a second side of the first deposition area opposite to the first pumping channel 142. The one or more lateral openings 145 of the first pumping channel 142 and the one or more lateral openings 145 of the second pumping channel may be directed toward the first deposition area 121 in some embodiments. Pumping uniformity can be improved and the flow of the process gas in the vacuum chamber can be adjusted as appropriate.

[00116] FIG. 4A shows an apparatus 400 for vacuum deposition on a substrate in a sectional view. FIG. 4B shows the apparatus 400 in a perspective view. The apparatus 400

may partially correspond to the apparatus 100 shown in FIG. 1A and FIG. 1B, and corresponding features are not repeated here.

[00117] The apparatus 400 includes a vacuum chamber 110. In some embodiments, the vacuum chamber 110 may have the general shape of a cuboid and comprise at least six outer side walls, i.e. a top wall, a bottom wall, a left side wall, a right side wall, a front side wall, and a rear side wall.

[00118] The apparatus 400 may include a plurality of pumping channels 410, including the first pumping channel 142 and a second pumping channel 144. Further pumping channels may be provided. For example, four or more pumping channels, six or more pumping channels, or nine or more pumping channels may be provided.

[00119] In some embodiments, which may be combined with other embodiments described herein, the pumping channels may extend parallel with respect to each other, particularly from the first side wall 112, e.g. the top wall, to the second side wall 114, e.g. the bottom wall, of the vacuum chamber 110. In some embodiments, one or more pumping channels may extend only partially from the first side wall 112 to the second side wall 114. In some embodiments, some pumping channels or all pumping channels may extend from a respective first pump opening provided in the first side wall 112 through to a respective second pump opening provided in the second side wall 114.

[00120] The plurality of pumping channels may be arranged according to one or more of the following pumping channel arrangements (i) to (vi):

(i) At least one pumping channel may run along an inner corner of the vacuum chamber 110. In other words, at least one pumping channel may be arranged directly adjacent to a corner in the interior of the vacuum chamber 110. For example, two channel walls of the at least one pumping channel may extend in direct contact to the inner surfaces of the two side walls of the vacuum chamber which form the respective inner corner of the vacuum chamber. Alternatively, two channel walls of the at least one pumping channel may be formed by portions of the inner surfaces of the two side walls of the vacuum chamber

which form the respective corner of the vacuum chamber.

(ii) Two pumping channels may run along two adjacent inner corners of the vacuum chamber and/or along two opposite inner corners of the vacuum chamber.

(iii) Four pumping channels may run along the four inner corners of the vacuum chamber.

5 For example, in the embodiment shown in FIG. 4A, a pumping channel is arranged in each of the four inner corners of the vacuum chamber. The four pumping channels may run vertically in a top-bottom direction along the four vertical inner corners of the vacuum chamber. It is noted that the vacuum channels may be formed as structural elements of the vacuum chamber and may increase the stability of the vacuum chamber at the four
10 vertical corners of the vacuum chamber.

(iv) At least one pumping channel, e.g. the first pumping channel 142 in the embodiment depicted in FIG. 4A, may extend in a center area of the vacuum chamber. In some embodiments, the at least one pumping channel may provide a center support of the vacuum chamber. In particular, the at least one pumping channel may extend self-
15 supportingly between the first side wall 112 and the second side wall 114 of the vacuum chamber. The channel walls may contact the main body of the vacuum chamber only at the respective axial ends of the channel.

(v) One, two, three, four or more pumping channels may extend along a side wall of the vacuum chamber which connects the top wall and the bottom wall, respectively. In
20 particular, a pumping channel may be arranged in a center section of the front side wall and may extend in the top-bottom direction, a pumping channel may be arranged in a center section of the rear side wall and may extend in the top-bottom direction, a pumping channel may be arranged in a center section of the left side wall and may extend in the top-bottom direction, and/or a pumping channel may be arranged in a center section of the
25 right side wall and may extend in the top-bottom direction.

(vi) Three or more pumping channels may be arranged spaced-apart from each other in a linear setup. A row of pumping channels may be formed. For example, in the embodiment depicted in FIG. 4A, three pumping channels are arranged to form a first row of pumping channels 412. Further rows of pumping channels may be provided, e.g. a second row of

pumping channels 413 and/or a third row of pumping channels 414. The rows of pumping channels may be spaced apart from each other, e.g. at a distance from 30 cm to 100 cm.

[00121] The plurality of pumping channels 410 may be provided in an array of pumping channels which allows the substrates to be transported between two adjacent rows of pumping channels, respectively.

[00122] For example, the first substrate transportation path T1 may extend between a first row of pumping channels 412 and a second row of pumping channels 413, and/or the second substrate transportation path T2 may extend between the second row of pumping channels 413 and a third row of pumping channels 414. Each row of pumping channels may include three or more pumping channels which may be spaced apart from each other, particularly at regular distances. For example, two adjacent pumping channels of a row of pumping channels may be spaced apart by a distance between 50 cm and 100 cm.

[00123] A deposition area may be arranged between two adjacent pumping channels of a row of pumping channels, respectively. For example, in the embodiment depicted in FIG. 4A, a deposition area is arranged between each adjacent pair of pumping channels of a row of pumping channels. A plurality of deposition areas 420, e.g. six or more deposition areas, may be provided. Each deposition area of the plurality of deposition areas 420 may be adapted to house at least one deposition source.

[00124] In some embodiments, which may be combined with other embodiments described herein, some deposition areas of the plurality of deposition areas may not house a deposition source. For example, in the embodiment shown in FIG. 4B, deposition sources are only arranged between pumping channels of the second row of pumping channels 413, i.e. in a central area of the vacuum chamber. A first deposition source 120 and a further deposition source 415 may be provided.

[00125] As pumping channels may be positioned on both sides of the deposition areas, respectively, the pumping uniformity and the pumping efficiency can be increased.

In particular, the pumping channels may guarantee a more uniform pressure distribution in the main volume of the vacuum chamber from a top area through a middle area to a bottom area of the vacuum chamber. In particular, the pressure difference between a middle area of the vacuum chamber in a top-bottom direction and the top and bottom areas can be reduced by providing a plurality of pumping channels as described herein. In some embodiments, the opening pattern provided in each of the pumping channels may extend over more than 50%, particularly over more than 70% of the length direction of the respective pumping channel. In particular, at least one opening of the opening pattern may be provided in a center section of the pumping channel.

[00126] The first deposition source 120 and/or the further deposition source 415 may be configured as bi-directional deposition sources which are configured to deposit material toward the first substrate transportation path T1 and toward the second substrate transportation path T2. Substrates which are transported along the first substrate transportation path T1 on a front side of the deposition sources may be coated, and substrates which are transported along the second substrate transportation path T2 on a rear side of the deposition sources may be coated.

[00127] In some embodiments, which may be combined with other embodiments described herein, the first deposition source 120 may be a sputter deposition source including a first rotatable sputter target 421 and a second rotatable sputter target 422 which may be arranged adjacent to each other in a lateral direction, e.g. in the second direction H which may be a horizontal direction. In some embodiments, the first pumping channel 142 may be arranged adjacent to the first rotatable sputter target 421 and a second pumping channel 144 may be arranged adjacent to the second rotatable sputter target 422. The first rotatable sputter target 421 and the second rotatable sputter target 422 may extend linearly in the first direction (V) which may be a vertical direction. The first pumping channel 142 and the second pumping channel 144 may extend parallel to and/or in line with the first rotatable sputter target 421 and the second rotatable sputter target 422.

[00128] The first rotatable sputter target 421 and the second rotatable sputter target 422 of one of the deposition sources may be configured as oppositely charged electrodes, e.g. as an anode and as a cathode. AC sputtering, MF sputtering or RF sputtering may be possible. Alternatively or additionally, at least one deposition source may be configured as a DC deposition source.

[00129] A driving unit 403 of the first deposition source 120 may be provided outside the vacuum chamber 110, e.g. on the bottom wall of the vacuum chamber. The driving unit 403 may be configured for rotating one or more rotatable sputter targets of the first deposition source 120 and/or for pivoting one or more magnetrons of the first deposition source 120.

[00130] A first transport device 404 may be provided for transporting a substrate along the first substrate transportation path T1. The first transport device 404 may include a magnetic levitation system in some embodiments. The first transport device 404 may be configured for transporting the substrate at a first distance D1 past the first deposition source 120 in a first horizontal direction. The first distance D1 may be understood as the minimum distance between the first substrate transportation path T1 and a center of a deposition source which is configured for coating the substrate during transport. The first distance D1 may be configured to obtain a good deposition result.

[00131] In some embodiments, the first transport device 404 may be configured for shifting the coated substrate away from the first deposition source 120 in a path switching direction X which may be perpendicular to the first substrate transportation path T1, e.g. by a second distance D2. The second distance D2 may be between 50 mm and 200 mm, particularly less than 120 mm in some embodiments.

[00132] In some embodiments, the first transport device 404 may be configured for transporting the substrate in a second horizontal direction which may be opposite with respect to the first horizontal direction such that the substrate may enter and exit the

vacuum chamber on the same side, e.g. through a slit passage 425 provided in one of the lateral side walls of the vacuum chamber.

[00133] In some embodiments, at least one lateral side wall of the vacuum chamber 110, e.g. the right lateral side wall, may be provided with one or more slit passages 425 configured for guiding the substrates into the vacuum chamber before coating and/or out of the vacuum chamber after coating. In some embodiments, slit passages may be provided in opposite lateral side walls of the vacuum chamber, in order to allow the substrates to exit the vacuum chamber on an opposite side.

[00134] In some embodiments, which may be combined with other embodiments described herein, a second transport device 405 may be provided for transporting a further substrate along the second substrate transportation path T2 on an opposite side of the first deposition source 120. The second transport device 405 may be configured for transporting the further substrate at the first distance D1 past the first deposition source 120 on the other side of the first deposition source, particularly in the first horizontal direction.

[00135] In some embodiments, the second transport device 405 may be configured for shifting the coated substrate away from the first deposition source 120 in the path switching direction X which may be perpendicular to the second substrate transportation path T2, e.g. by the second distance D2.

[00136] In some embodiments, the second transport device 405 may be configured for transporting the substrate in a second horizontal direction which may be opposite with respect to the first horizontal direction such that the substrate may enter and exit the vacuum chamber on the same side, e.g. through a slit passage 425.

[00137] As is schematically depicted in FIG. 4B, the apparatus 400 may include a plurality of vacuum pumps 430, e.g. turbomolecular pumps, for evacuating at least some pumping channels of the plurality of pumping channels 410. In particular, the pumping channels of the second row of pumping channels 413 may be evacuated from at least one

side thereof or from both sides thereof. For example, the first vacuum pump 401 is connected to a first pump opening provided in the top wall of the vacuum chamber, and the second vacuum pump 402 is connected to a second pump opening provided in the bottom wall of the vacuum chamber, wherein the second pumping channel 144 may extend from the first pump opening to the second pump opening. Thus, the second pumping channel 144 can be pumped from either side or from both sides thereof.

[00138] In some embodiments, vacuum pumps may only be connected to pumping channels (also referred to as “active” pumping channels herein) which are arranged adjacent to an active deposition area. An active deposition area as used herein may be understood as a deposition area housing a deposition source and configured for coating a substrate. No vacuum pump may be connected to pumping channels (also referred to as “inactive” pumping channels herein) which are arranged adjacent to an inactive deposition area. An inactive deposition area as used herein may be understood as a deposition area which may be configured to house a deposition source, but where no deposition source is actually arranged or which houses an unused deposition source.

[00139] In the embodiments shown in FIG. 4B, the pumping channels of the first row of pumping channels 412 and of the third row of pumping channels 414 are inactive pumping channels. Accordingly, no vacuum pumps may be connected to these pumping channels. For example, the first pump openings and the second pump openings which are provided in the first side wall 112 and in the second side wall 114 of the vacuum chamber and belong to “inactive” pumping channels may be closed during operation of the apparatus, e.g. via lids such as blind flanges. A flexible deposition module can be provided.

[00140] FIG. 5A shows a sectional view of an apparatus 500 in accordance with embodiments described herein. FIG. 5B shows a perspective view of the apparatus 500 of FIG. 5A.

[00141] The apparatus 500 essentially corresponds to the apparatus 400 shown in FIG. 4A and FIG. 4B, and corresponding features are not repeated here.

[00142] The basic structure of the vacuum chamber 110 and of the plurality of pumping channels 410 corresponds to the apparatus of FIG. 4A and FIG. 4B. However, in the apparatus 500 of FIG. 5A, the first row of pumping channels 412 and the third row of pumping channels 414 include active pumping channels, respectively, which are arranged adjacent to active deposition areas. The second row of pumping channels 413 includes inactive pumping channels which are arranged adjacent to inactive deposition areas. A plurality of vacuum pumps 430 may be connected to the active pumping channels, particularly to both sides of the active pumping channels. No vacuum pumps may be connected to the inactive pumping channels. The inactive pump openings 501 which are associated to the inactive pumping channels may be closed, e.g. via a lid such as a blind flange.

[00143] A plurality of deposition sources 502 may be arranged in the active deposition areas, e.g. between the active pumping channels of the first row of pumping channels 412 and/or the third row of pumping channels 414, respectively.

[00144] The first substrate transportation path T1 may extend at the first distance D1 from the deposition sources configured for coating the substrates which are guided along the first substrate transportation path T1. The second substrate transportation path T2 may also extend at the first distance D1 from the deposition sources configured for coating the substrates which are guided along the second substrate transportation path T2. Uniform coating results can be achieved.

[00145] In the embodiment depicted in FIG. 5A, the deposition sources of the plurality of deposition sources 502 may be located close to a lateral side wall of the vacuum chamber 110, respectively, e.g. at a third distance D3 of 300 mm or less, particularly 200 mm or less. Accordingly, the maintenance of the deposition sources and/or the exchange of the deposition sources may be facilitated. For example, as is schematically depicted in FIG. 5B, the plurality of deposition sources 502 may be arranged behind side wall doors of the vacuum chamber 110 which can be disassembled for maintenance of the deposition sources.

[00146] FIG. 5C shows a modification of the apparatus 500 of FIG. 5A. In the embodiment shown in FIG. 5C, the apparatus 500 includes an inner partition wall 520 which is arranged between the first substrate transportation path T1 and the second substrate transportation path T2. Gas separation between a first coating area and a second coating area of the vacuum chamber 110 may be improved. For example, substrates which are transported along the first substrate transportation path T1 may be coated with a first material, and substrates which are transported along the second substrate transportation path T2 may be coated with a second material different from the first material. A mixture of the respective process gases in the main volume of the vacuum chamber can be reduced and the deposition quality can be improved.

[00147] In some embodiments, the inner partition wall 520 may extend between the pumping channels of the second row of pumping channels 413, respectively. In some embodiments, the inner partition wall 520 may be cooled, e.g. with a water cooling system.

[00148] FIG. 6 shows a perspective view of an apparatus 600 in accordance with embodiments described herein. The apparatus 600 essentially corresponds to the apparatus 400 shown in FIG. 4A and FIG. 4B, and corresponding features are not repeated here. In particular, the basic structure of the vacuum chamber 110 and of the plurality of pumping channels 410 corresponds to the apparatus of FIG. 4A and FIG. 4B.

[00149] In the apparatus 600, the active deposition areas may alternatively or additionally be pumped by side pumps 625 which may be connected to one or more lateral side walls of the vacuum chamber 110. As will be apparent to the skilled person, vacuum pumps may also be connected to at least some pumping channels the plurality of pumping channels 410, e.g. to the active pumping channels, i.e. the pumping channels of the first row of pumping channels 412 and of the third row of pumping channels 414.

[00150] In some embodiments, the side pumps 625 may be connected to side wall doors 620 which may be provided for easy access of the deposition sources which may be

housed behind the side wall doors. In some embodiments, the side pumps may be configured as cryo-pumps.

[00151] FIG. 7 shows an apparatus 700 according to embodiments disclosed herein in a sectional view. The basic structure of the vacuum chamber 110 and of the plurality of pumping channels 410 of the apparatus may correspond to the apparatus of FIG. 4A and FIG. 4B, and these details are not repeated here.

[00152] In the embodiment shown in FIG. 7, the pumping channels of adjacent rows of pumping channels are active pumping channels, e.g. of the second row of pumping channels 413 and of the third row of pumping channels 414. The pumping channels of at least one row of pumping channels may be inactive pumping channels, e.g. of the first row of pumping channels 412. The inactive pumping channels are arranged adjacent to inactive deposition areas 730 where no deposition source may be arranged. Different arrangements are likewise possible.

[00153] In some embodiments, which may be combined with other embodiments described herein, a path switching module 720 may be provided for transferring a substrate from the first substrate transportation path T1 to the second substrate transportation path T2, or vice versa. The path switching module 720 may be arranged in a path switching chamber 710 which may be connected to the vacuum chamber 110. In further embodiments, the path switching module 720 may be arranged in a main volume of the vacuum chamber 110, e.g. in a path switching area of the vacuum chamber 110. Internal or external path switching modules are possible.

[00154] The substrates to be coated may be transported along the second substrate transportation path T2 while being coated by at least one deposition source which is arranged in an active deposition area, may be transferred in a path switching direction X toward the first substrate transportation path T1, and may then be transported along the first substrate transportation path T1, while being coated by at least one further deposition source which is arranged in an active deposition area. An inverted transport of the substrates may similarly be possible.

[00155] The first substrate transportation path T1 may be essentially parallel to the second substrate transportation path T2. In some embodiments, the substrate may be transported along the first substrate transportation path T1 and along the second substrate transportation path T2 in opposite directions. In some embodiments, the path switching direction X extends perpendicular to the first substrate transportation path T1 and/or to the second substrate transportation path T2, e.g. in the forward-rearward direction of FIG. 7. The substrate transportation paths may extend in the left-right direction of FIG. 7.

[00156] The path switching module 720 may maintain an orientation of the substrate during the path switching operation. For example, the substrate may be linearly moved or shifted from the second substrate transportation path T2 to the first substrate transportation path T1 (or vice versa), without a rotational movement of the substrate. Accordingly, the same main surface of the substrate may be coated during transport along the first substrate transportation path T1 and along the second substrate transportation path T2. In other embodiments, the path switching module 720 may invert the orientation of the substrate during the path switching operation. For example, the substrate may be rotated during the path switching operation. Accordingly, a first main surface of the substrate may be coated during transport along the first substrate transportation path and an opposite second main surface of the substrate may be coated during transport along the second substrate transportation path. A one-side coating apparatus and/or a two-side coating apparatus may be provided.

[00157] It will be apparent to the skilled person that also the inactive deposition areas 730 shown in FIG. 7 may house deposition sources configured to coat the substrates which are guided along the first substrate transportation path T1. Accordingly, a two-side coating apparatus may also be provided by activating further deposition areas.

[00158] In some embodiments, which may be combined with other embodiments described herein, at least one deposition source may be configured for chemical vapor deposition. For example, at least one deposition source may include at least one of a gas lance and an antenna. The gas lance may be configured for injecting a process gas into the main volume of the vacuum chamber. In some embodiments, the deposition source may

extend essentially parallel to at least one pumping channel arranged adjacent to the deposition source.

[00159] In some embodiments, which may be combined with other embodiments described herein, at least a part of a deposition source may be fixed at the first pumping channel 142. For example, at least one of a gas inlet, a gas lance and/or a shielding plate may be fixed to the first pumping channel 142. In some embodiments, the pumping channels may be configured as holders or supports of parts of the deposition sources, e.g. of shielding plates and/or gas inlets.

[00160] FIG. 8A is a sectional view of an apparatus 800 in accordance with embodiments described herein. FIG. 8B is a perspective view of the apparatus of FIG. 8A.

[00161] The apparatus 800 includes a vacuum chamber 110 with a first side wall 112, e.g. a top wall, and a second side wall 114, e.g. a bottom wall opposite to the first side wall 112. Further, the apparatus 800 includes a plurality of deposition areas 420 which are configured to house a deposition source, respectively.

[00162] The apparatus 800 includes a plurality of pumping channels 410 which extend through the vacuum chamber adjacent to at least one of the plurality of deposition areas 420, respectively, and are configured to be evacuated from a first side thereof and/or from a second side thereof, respectively. Details of the pumping channels 410 are described elsewhere and are not repeated here.

[00163] In the embodiment of FIG. 8A and FIG. 8B, a first pumping channel 142 is arranged on a first side of a first deposition source 120, and a second pumping channel 144 is arranged on a second side of the first deposition source 120 opposite to the first side. The first pumping channel may be pumped from a first pump opening 113 provided in the first side wall 112, and the second pumping channel 144 may be pumped from a second channel-first pump opening 116 provided in the first side wall 112.

[00164] Each pumping channel may be provided with one or more lateral openings in at least one channel wall which may be directed to one of the deposition areas. In some embodiments, lateral openings may be provided in opposite channel walls of at least one

pumping channel which is arranged between adjacent deposition areas. For example, the first pumping channel 142 of FIG. 8A is arranged between two adjacent deposition areas.

[00165] In some embodiments, a plurality of rows of pumping channels may be provided, e.g. a first row of pumping channels 412, a second row of pumping channels 413, and/or a third row of pumping channels 414. Each row of pumping channels may include three or more pumping channels, particularly five pumping channels, which may optionally be arranged at corresponding distances.

[00166] A first substrate transportation path T1 may extend between the first row of pumping channels 412 and the second row of pumping channels 413, and a second substrate transportation path T2 may extend between the second row of pumping channels 413 and the third row of pumping channels 414. Further, in some embodiments, a first return path and a second return path may be provided. Substrates which have been transported and coated along the first substrate transportation path T1 may be guided back to a first chamber entrance along the first return path, and substrates which have been transported and coated along the second substrate transportation path T2 may be guided back to a second chamber entrance along the second return path.

[00167] In some embodiments, at least a subset of the plurality of pumping channels or each pumping channel of the plurality of pumping channels may be provided with the same cross-sectional shape, length, form, width and/or opening pattern. In particular, the pumping channels may be identically shaped in some embodiments.

[00168] The apparatus may be provided as a modular vacuum deposition apparatus. Therein, an adjustable first subset of the plurality of deposition areas and an adjustable first subset of the plurality of pumping channels may be configured as active deposition areas and as active pumping channels, respectively, and the remaining deposition areas and the remaining pumping channels may be configured as inactive deposition areas and inactive pumping channels, respectively. No vacuum pump may be connected to the inactive pumping channels, and no deposition source may be housed in the inactive deposition areas. FIG. 8A and FIG. 8B show the apparatus in an inactive state, i.e. without

deposition sources and vacuum pumps. Inactive pumping channels may be closed at both ends thereof with a lid, e.g. with a blind flange.

[00169] FIG. 8C shows a modification of the apparatus of FIG. 8A in a sectional view. FIG. 8D is a perspective view of the apparatus of FIG. 8C.

5 [00170] In the embodiment of FIG. 8C and FIG. 8D, at least some deposition areas of the plurality of deposition areas 420, e.g. the first deposition area 121, are configured as active deposition areas, and at least some of the plurality of pumping channels 410 are configured as active pumping channels, e.g. the first pumping channel 142 and the second pumping channel 144.

10 [00171] For example, a first deposition source 120, e.g. a sputter deposition source, may be arranged in the first deposition area 121. The first deposition source may include at least one rotatable sputter target which may extend in a first direction, e.g. parallel to the first and second pumping channels. In other words, the rotation axis of the rotatable sputter target may be parallel to the pumping channels. The rotation of the rotatable
15 sputter target may be driven by a driving unit 403 which may not be arranged inside the vacuum chamber. The rotatable sputter target may be configured for depositing a first material on a substrate.

[00172] In some embodiments, at least one deposition source provided in one of the active deposition areas may be configured as a sputter deposition source with a planar
20 sputter target 810 which may be configured for depositing a second material on a substrate. The second material may be different from the first material. A layer stack including two, three or more different materials may be deposited on a substrate which is guided along the first substrate transportation path P1.

[00173] In some embodiments, at least one (inactive) deposition area may house a
25 path switching module 720 configured to transfer a substrate between the first substrate transportation path T1 and the second substrate transportation path T2. The path switching module 720 may be configured to move the substrate in a path switching direction X which may be perpendicular to the substrate transportation paths. Accordingly, a path

switching module configured to transfer a substrate between two or more substrate transportation paths may be arranged in the vacuum chamber, e.g. in at least one (inactive) deposition area.

[00174] In some embodiments, which may be combined with other embodiments described herein, at least two path switching modules may be provided. A first path switching module may be provided inside the vacuum chamber in a first transfer compartment, e.g. in an inactive deposition area, and a second path switching module may be provided inside the vacuum chamber in a second transfer compartment, e.g. in a further inactive deposition area. A substrate may be transported along a circumferential path in the vacuum chamber, e.g. when the first path switching module transfers the substrate from the first substrate transportation path T1 to the second substrate transportation path T2 and the second path switching module transfers the substrate from the second substrate transportation path T2 to the first substrate transportation path T1. For example, two outer deposition areas in the embodiment of FIG. 8A (right and left deposition areas) may be provided with path switching modules, and two inner deposition areas in the embodiment of FIG. 8A may be configured as active deposition areas which house a deposition source, respectively.

[00175] As will be apparent to the skilled person, further deposition sources may be provided in any of the plurality of deposition areas, e.g. at least one or more of a CVD deposition source or a PVD deposition source.

[00176] A change from an active deposition area to an inactive deposition area may be possible in a quick and easy way. In some embodiments, an exchange of a deposition source, e.g. from a rotatable cathode to a planar cathode or from a PVD deposition source to CVD deposition source may be possible. In some embodiments, it may be possible to change from an active deposition area which houses a deposition source to a transfer area which houses a path switching module. Accordingly, the apparatus 800 can be adapted as appropriate to the type of substrate to be coated.

[00177] The apparatus 800 shown in FIG. 8A includes a total of twelve deposition areas. An arbitrary subset of deposition areas may house a deposition source. For example, three, six, nine or twelve deposition sources may be provided. Further, the apparatus 800 includes fifteen pumping channels. One or two vacuum pumps may be connected to an arbitrary subset of pumping channels, particularly to the pumping channels arranged adjacent to an active deposition area. A plurality of vacuum pumps may be provided.

[00178] The vacuum chamber 110 of the apparatus 800 may be very compact. For example, each row of pumping channels may include five pumping channels with four deposition areas provided therebetween, respectively. The outer dimension of the vacuum chamber in the direction of the first substrate transportation path T1 may be 6 m or less, particularly 5 m or less, more particularly from 4 m to 4.5 m.

[00179] In some embodiments, which may be combined with other embodiments described herein, at least two pumping channels are arranged on opposite sides of the substrate transportation path. Alternatively or additionally, at least two pumping channels are arranged next to each other on the same side of the substrate transportation path.

[00180] FIG. 9 is a perspective view of a pumping arrangement 900 including a first pumping channel 142. The pumping arrangement 900 may be part of any of the apparatuses described herein. If an apparatus according to embodiments described herein includes two or more pumping channels, each pumping channel may be configured similar to or identical to the first pumping channel 142 shown in FIG. 9.

[00181] The first pumping channel 142 may extend in a length direction, which may be a vertical direction or a horizontal direction. In some embodiments, the first pumping channel may be configured as an essentially rectangular tube with a channel wall which surrounds the inner volume of the first pumping channel 142. In the embodiment shown in FIG. 10, the first pumping channel is configured as a tube with a square cross section. Alternative sectional shapes, e.g. round or circular sectional shapes are possible.

[00182] The length of the first pumping channel 142 in the length direction may be 1 m or more, particularly 2 m or more. Alternatively or additionally, a width dimension or a diameter of the first pumping channel may be 20 cm or more and 50 cm or less, particularly about 30 cm. For example, the first pumping channel may have the cross-sectional shape of a square with a side length from 20 cm to 50 cm, particularly with a side length of about 30 cm. Alternatively or additionally, a cross-sectional area of the first pumping channel may be 400 cm³ or more and 2000 cm³ or less, particularly about 900 cm³. Alternatively or additionally, the first pumping channel may have a constant cross-sectional shape from the first end of the first pumping channel to the second end of the first pumping channel.

[00183] The first pumping channel may extend continuously and/or linearly from a first end to a second end. The first end may be connectable to a first side wall of a vacuum chamber, and the second end may be connectable to a second side wall of the vacuum chamber. In other embodiments, the first pumping channel may extend discontinuously and/or along a curved path.

[00184] A first vacuum pump 401 may be connected to the first end of the first pumping channel for evacuating the first pumping channel from a first side, and/or a second vacuum pump 402 may be connected to the second end of the first pumping channel for evacuating the first pumping channel from a second, opposite side.

[00185] In some embodiments, a third vacuum pump 901 and/or a fourth vacuum pump 902 may be connected to a center portion of the first pumping channel in the length direction of the first pumping channel. The third vacuum pump 901 and/or the fourth vacuum pump 902 may optionally be turbo pumps. For example, the first pumping channel may have at least one pump opening 903 for connecting a vacuum pump to one of the lateral channel walls of the first pumping channel, e.g. to a center portion of one of the lateral channel walls. In some embodiments, at least one vacuum pump which is connected to a lateral channel wall of the pumping channel may be installed in an atmosphere box. The atmosphere box which encloses the vacuum pump may be arranged

inside the main volume of the vacuum chamber. A pipe for guiding a cable of the vacuum pump may be provided inside the first pumping channel.

[00186] One or more lateral openings 145 may be provided in at least one of the channel walls of the first pumping channel. The one or more lateral openings 145 may form an opening pattern which may extend in the length direction of the first pumping channel, e.g. over more than 50%, particularly more than 70%, more particularly more than 90% of the length of the first pumping channel.

[00187] In some embodiments, which may be combined with other embodiments described herein, an opening dimension of the opening pattern and/or a distance between adjacent lateral openings of the opening pattern may vary in the length direction of the first pumping channel such as to obtain an essentially uniform gas flow from the main volume of the vacuum chamber into the first pumping channel 142 over the length direction of the first pumping channel 142.

[00188] FIG. 10A to FIG. 10D show examples of opening patterns which may be provided in at least one of the channel walls of the first pumping channel (or in any other pumping channel). The opening pattern may provide a larger opening area per length unit in a central section of the first pumping channel 142, i.e. in a section of the first pumping channel which is distant from the vacuum pumps connected to the first end and/or to the second end of the vacuum channel. For example, the opening area per length unit may be smaller in the upper and lower thirds of the first pumping channel as compared to the central third of the first pumping channel.

[00189] For example, the opening patterns shown in FIG. 10A, FIG. 10B, and FIG. 10D extend in the length direction of the pumping channel and are configured as a single slit opening, respectively. A width of the slit opening may vary in the length direction of the pumping channel. For example, a slit width may gradually decrease from a center section of the pumping channel toward a first end and/or toward a second end of the pumping channel. Pumping uniformity can be improved in a center area of the vacuum chamber. The first opening pattern 910 shown in FIG. 10A may essentially have

the shape of a long diamond with essentially straight edges. The second opening pattern 911 shown in FIG. 10B may essentially have an oval shape with a long major axis and a short minor axis. The fourth opening pattern 913 shown in FIG. 10D may have a shape with a non-linearly increasing and decreasing slit width in the length direction of the first pumping channel.

[00190] For example, the fourth opening pattern 912 shown in FIG. 10C extends in the length direction of the pumping channel and is configured as a plurality of openings which may optionally be round or circular. An opening diameter of the plurality of openings may vary in the length direction of the pumping channel. For example, the opening diameter of the openings may decrease from a center section of the pumping channel toward a first end and/or toward a second end of the pumping channel. Pumping uniformity can be improved from a center area of the vacuum chamber to an upper and lower area of the vacuum chamber. Alternatively, a distance between adjacent openings may vary in the length direction of the pumping channel.

[00191] In some embodiments, the one or more lateral openings are provided in a channel wall which is an integral part of the pumping channel. In other words, the one or more lateral openings 145 may be directly machined in the channel wall. In some embodiments, the one or more lateral openings are provided in inserts which can be added to and/or removed from a pumping channel. In this case, the opening pattern of at least one of the pumping channels can be exchanged and/or replaced with a different opening pattern as appropriate. For example, a first opening pattern may be adapted to a first type of deposition source, and a second, different opening pattern may be adapted to a second type of deposition source which may be operated with a different gas load and/or gas distribution.

[00192] For example, at least one pumping channel may include a main channel body having a tubular shape with a longitudinal slit configured to fix an insert which is provided with the plurality of lateral openings. Flexibility of the apparatus can be improved.

[00193] FIG. 11 is a flow diagram illustrating a method of depositing a layer on a substrate according to some embodiments described herein.

[00194] In box 1010, a vacuum chamber 110 having a first side wall 112 with a first pump opening 113 and a second side wall 114 with a second pump opening 115 is provided. A first pumping channel 142 is arranged adjacent to a first deposition area 121 in the vacuum chamber. The first pumping channel may extend from the first pump opening 113 to the second pump opening 115 and comprise one or more lateral openings 145 in a channel wall. The first pumping channel 142 may include some features or all features of a pumping channel described herein. Further pumping channels may be provided in some embodiments.

[00195] In box 1020, a substrate is transported along a first substrate transportation path T1 through the vacuum chamber 110 past a first deposition source 120 arranged in the first deposition area 121.

[00196] In box 1030, one or more layers are deposited on a surface of the substrate, while the vacuum chamber 110 is evacuated by pumping from the first pump opening 113 and/or from the second pump opening 115, e.g. with turbomolecular vacuum pumps.

[00197] In some embodiments, two, three, four or more pumping channels may be provided, and the main volume of the vacuum chamber may be evacuated by vacuum pumping from one side or from both sides of at least some of the two, three, four or more pumping channels.

[00198] In some embodiments, at least one layer may be deposited on the substrate by physical vapor deposition, e.g. by sputtering, particularly from a rotatable target and/or from a flat target.

[00199] In some embodiments, at least one layer may be deposited on the substrate by chemical vapor deposition.

[00200] In some embodiments, a layer stack including two, three, four or more layers is deposited on a first main surface of the substrate. In some embodiments, both main surfaces of the substrate may be coated, e.g. with a layer stack including two, three or more layers.

5 [00201] In some embodiments, the substrate is laterally transferred from the first substrate transportation path T1 to a second substrate transportation path T2 which may extend essentially parallel with respect to the first substrate transportation path T1. Then, the substrate may be transported along the second substrate transportation path T2, or vice versa.

10 [00202] In some embodiments, a further layer may be deposited on the substrate, while the substrate is transported along the second substrate transportation path, e.g. with the first deposition source which may be a bi-directional deposition source, or with a further deposition source.

15 [00203] According to a further aspect described herein, a method of depositing a layer on a substrate is described. The method includes providing a vacuum chamber 110 with a first pump opening. A first pumping channel is arranged adjacent to a first deposition area in the vacuum chamber. The first pumping channel may extend from the first pump opening into the vacuum chamber and may include one or more lateral openings in a channel wall. The one or more lateral openings may form an opening
20 pattern which may extend along the length direction of the first pumping channel. According to the method, a substrate is transported along a first substrate transportation path through the vacuum chamber 110 past a first deposition source arranged in the first deposition area. The first deposition source may at least partially extend parallel to the length direction of the first pumping channel. One or more layers are deposited on a
25 surface of the substrate, while the vacuum chamber 110 is evacuated by vacuum pumping from the first pump opening.

[00204] The process gas flow may extend from a main volume of the vacuum chamber via the opening pattern into the interior of the first pumping channel which may be directly pumped by a first vacuum pump and/or a second vacuum pump.

5 [00205] While the foregoing is directed to embodiments of the disclosure, other and further embodiments of the disclosure may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

CLAIMS

1. An apparatus (100) for vacuum deposition on a substrate, comprising:

a vacuum chamber (110) comprising a first side wall (112) with a first pump opening (113) and a second side wall (114) with a second pump opening (115);

5 a first deposition area (121) configured for housing a first deposition source (120) for depositing a layer on a substrate;

a first substrate transportation path (T1) along which a substrate is to be transported which extends in the vacuum chamber (110) past the first deposition area; and

10 a first pumping channel (142) arranged adjacent to the first deposition area (121) and extending continuously or discontinuously from the first pump opening (113) to the second pump opening (115), wherein the first pumping channel (142) comprises one or more lateral openings (145) defining a first gas flow path (P1) from a main volume of the vacuum chamber into the first pumping channel.

15 2. The apparatus of claim 1, wherein the first pump opening (113) is provided in a top wall of the vacuum chamber, the second pump opening (115) is provided in a bottom wall of the vacuum chamber, and the first pumping channel (142) extends through the vacuum chamber (110) in a top-bottom direction, particularly continuously and/or along a straight line from the first pump opening (113) to the second pump opening (115).

20 3. The apparatus of claim 1 or 2, further comprising a second pumping channel (144) arranged adjacent to the first deposition area (121) on an opposite side with respect to the first pumping channel, wherein the second pumping channel (144) extends through the vacuum chamber (110) from a second channel-first pump opening (116) in the first side wall (112) to a second channel-second pump opening (117) in the second side wall (114) and comprises one or more lateral openings (145) defining a second gas flow path (P2)
25 from a main volume of the vacuum chamber into the second pumping channel.

4. The apparatus of any of claims 1 to 3, wherein the one or more lateral openings (145) of the first pumping channel (142) and/or of the second pumping channel (144) are directed towards the first deposition area (121), respectively.

5. The apparatus of any of the preceding claims, wherein the one or more openings form an opening pattern extending in a length direction of the first pumping channel (142), particularly wherein an opening dimension of the opening pattern and/or a distance between adjacent lateral openings (145) of the opening pattern varies in the length direction of the first pumping channel.

6. The apparatus of any of the preceding claims, wherein the first pumping channel is provided as an inner support wall of the vacuum chamber (110) extending from the first side wall (112) to the second side wall (114), particularly wherein the first pumping channel is a structural element of the vacuum chamber (110).

7. The apparatus of any of the preceding claims, wherein the first pumping channel (142) has an inner sectional area of 100 cm² or more and 5000 cm² or less, particularly 400 cm² or more and 2000 cm² or less, more particularly 800 cm² or more and 1000 cm² or less.

8. The apparatus of any of the preceding claims, wherein a first vacuum pump is connected to the first pump opening (113) and configured to evacuate the first pumping channel (142) from a first side, and/or wherein a second vacuum pump is connected to the second pump opening (115) and configured to evacuate the first pumping channel (142) from a second side.

9. The apparatus of any of the preceding claims, wherein a first deposition source (120) is arranged in the first deposition area (121) and extends essentially parallel to and in line with the first pumping channel (142), particularly a sputter deposition source comprising at least one rotatable sputter target or at least one planar sputter target (810).

10. The apparatus of claim 9, wherein the sputter deposition source comprises a first rotatable sputter target (421) and a second rotatable sputter target (422) arranged adjacent to each other in a lateral direction, wherein the first pumping channel (142) is arranged adjacent to the first rotatable sputter target (421) and a second pumping channel (144) is arranged adjacent to the second rotatable sputter target (422).

11. The apparatus of any of the preceding claims, wherein the first deposition source (120) is configured for chemical vapor deposition and/or comprises at least one of a gas lance and an antenna arranged in the first deposition area (121) and extending essentially parallel to and in line with the first pumping channel (142).

12. The apparatus of any of the preceding claims, wherein the first substrate transportation path (T1) is located on a front side of the first deposition area (121), and wherein a second substrate transportation path (T2) along which a substrate is to be transported extends in the vacuum chamber (110) past the first deposition area (121) on a rear side of the first deposition area opposite to the front side, particularly parallel to the first substrate transportation path (T1).

13. The apparatus of claim 12, wherein the first deposition source (120) is a bi-directional deposition source (123), particularly a bi-directional sputter device configured to deposit material toward the first substrate transportation path (T1) and toward the second substrate transportation path (T2).

14. The apparatus of claim 12 or 13, further comprising a first transport device, particularly a magnetic levitation system or a roller system, configured for transporting a substrate along the first substrate transportation path (T1), and/or a second transport device, particularly a magnetic levitation system or a roller system, configured for transporting a substrate along the second substrate transportation path (T2).

15. The apparatus of any of claims 12 to 14, further comprising a path switching module (720) for transferring a substrate from the first substrate transportation path (T1)

to the second substrate transportation path (T2), or vice versa, particularly, wherein the path switching module (720) is arranged in a path switching chamber (710) connected to the vacuum chamber (110) or in a path switching area of the vacuum chamber (110).

16. The apparatus of any of the preceding claims, wherein the first deposition area (121) is located on a front side of the first substrate transportation path (T1), and wherein a second deposition area (122) configured to house a second deposition source (124) is located on a rear side of the first substrate transportation path (T1) opposite to the front side.

17. The apparatus of claim 16, further comprising at least one or both of:

a third pumping channel (146) arranged on a first lateral side of the second deposition area (122) and extending through the vacuum chamber from a third channel-first opening provided in the first side wall (112) of the vacuum chamber to a third channel-second opening provided in the second side wall (114) of the vacuum chamber; and

a fourth pumping channel (148) arranged on a second lateral side of the second deposition area (122) opposite to the first lateral side and extending through the vacuum chamber from a fourth channel-first opening provided in the first side wall (112) of the vacuum chamber to a fourth channel-second opening provided in the second side wall (114) of the vacuum chamber.

18. The apparatus according to any of the preceding claims, wherein at least one of a gas inlet, a gas lance and a shielding plate is fixed at the first pumping channel (142).

19. The apparatus according to any one of the preceding claims, wherein the vacuum chamber (110) has the general shape of a cuboid and comprises a plurality of pumping channels (142, 144, 146, 148) respectively extending parallel with respect to each other from the first side wall to the second side wall, wherein the plurality of pumping channels is arranged according to one or more of the following:

- at least one pumping channel extends along an inner corner of the vacuum chamber;
- two pumping channels extend along two adjacent inner corners of the vacuum chamber;
- 5 • four pumping channels extend along the four inner corners of the vacuum chamber;
- at least one pumping channel extends in a center area of the vacuum chamber and provides a center support of the vacuum chamber;
- one, two, three, four or more pumping channels extend from the top wall to the
10 bottom wall along a lateral side wall of the vacuum chamber which connects the top wall and the bottom wall.

20. A deposition module for vacuum deposition on a substrate, comprising:

a vacuum chamber (110) having a first side wall (112) with a first pump opening (113);

15 at least one deposition source arranged in a first deposition area (121) in the vacuum chamber (110) and extending in a first direction (V);

a first substrate transportation path (T1) along which a substrate is to be transported which extends in the vacuum chamber (110) past the at least one deposition source; and

20 a first pumping channel (142) arranged adjacent to the at least one deposition source and extending from the first pump opening (113) essentially parallel to the at least one deposition source in the first direction (V), wherein the first pumping channel (142) comprises one or more lateral openings (145) which form an opening pattern extending in the first direction (V) and define a first gas flow path (P1) from a main volume of the vacuum chamber into the first pumping channel (142).

21. A method of depositing a layer on a substrate, comprising:

providing a vacuum chamber (110) having a first side wall (112) with a first pump opening (113), a second side wall (114) with a second pump opening (115), and a first pumping channel (142) which is arranged adjacent to a first deposition area, extends continuously or discontinuously from the first pump opening (113) to the second pump opening (115) and comprises one or more lateral openings;

transporting a substrate along a first substrate transportation path (T1) through the vacuum chamber (110) past a first deposition source arranged in the first deposition area (121); and

depositing a layer on a surface of the substrate, while evacuating the vacuum chamber by pumping from the first pump opening and/or from the second pump opening.

1 / 10

Fig. 1A

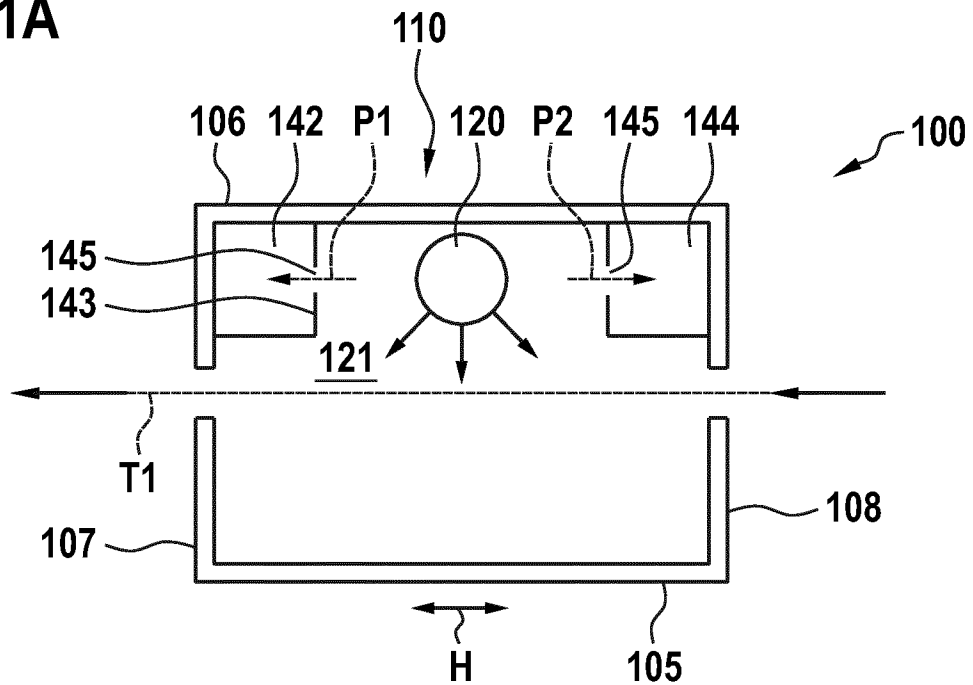
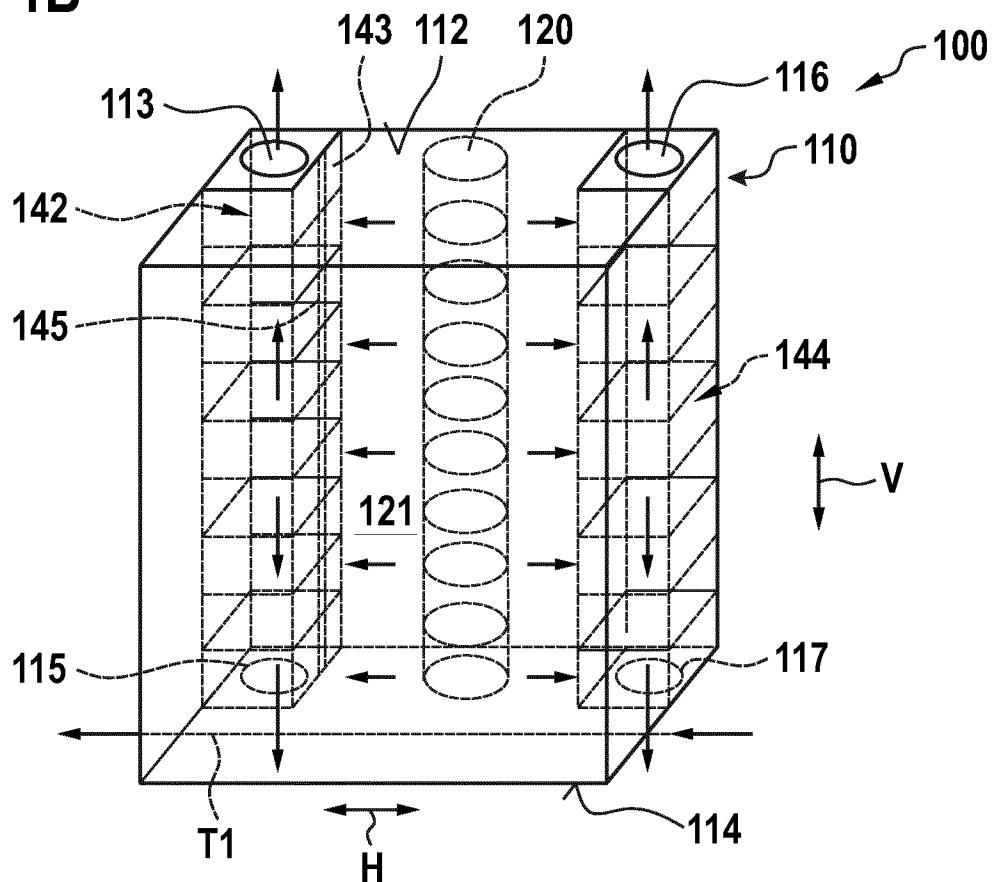


Fig. 1B



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Fig. 2

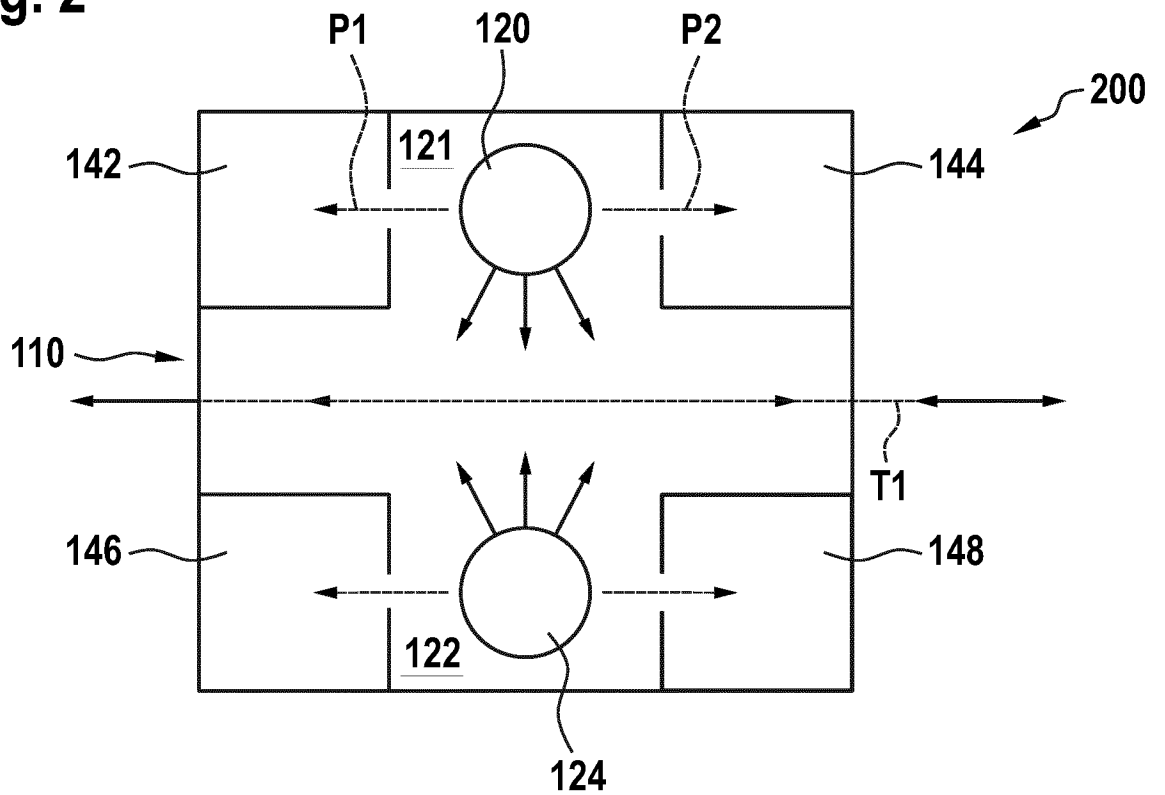
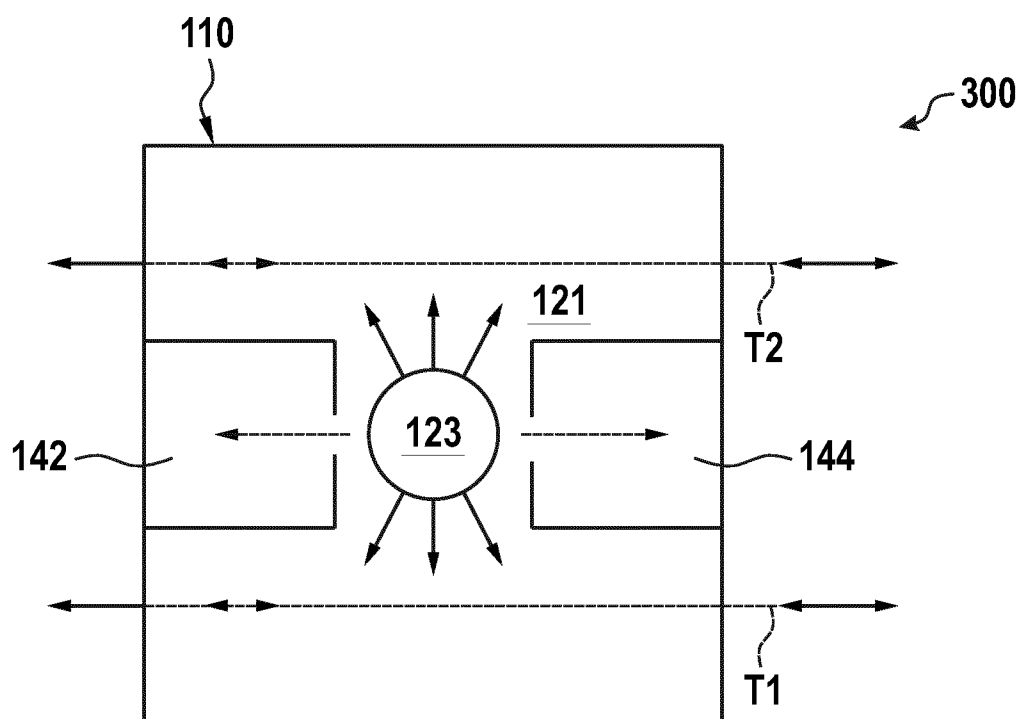


Fig. 3



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Fig. 5A

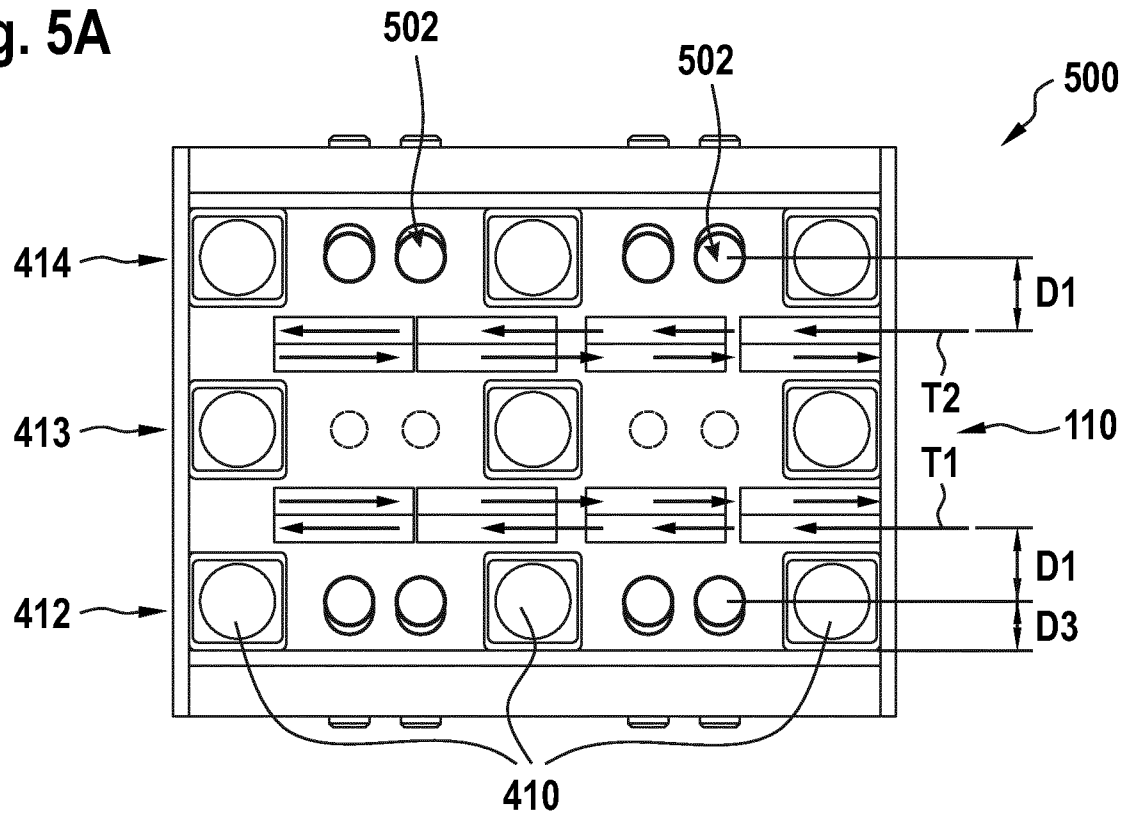
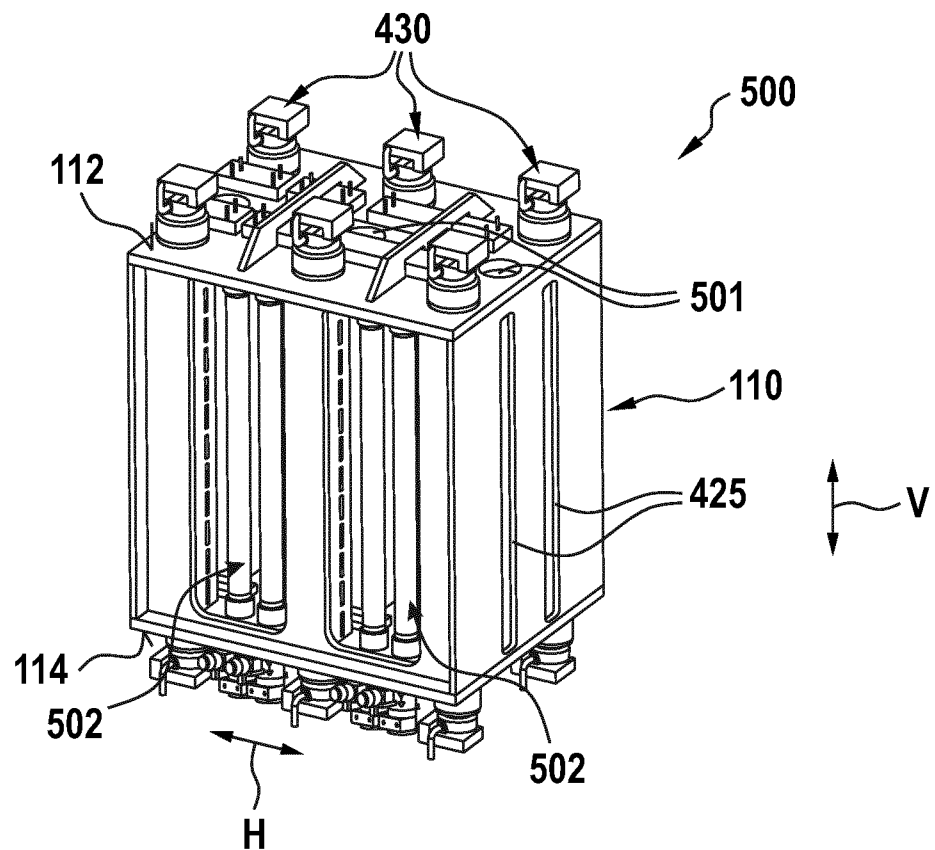


Fig. 5B



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Fig. 5C

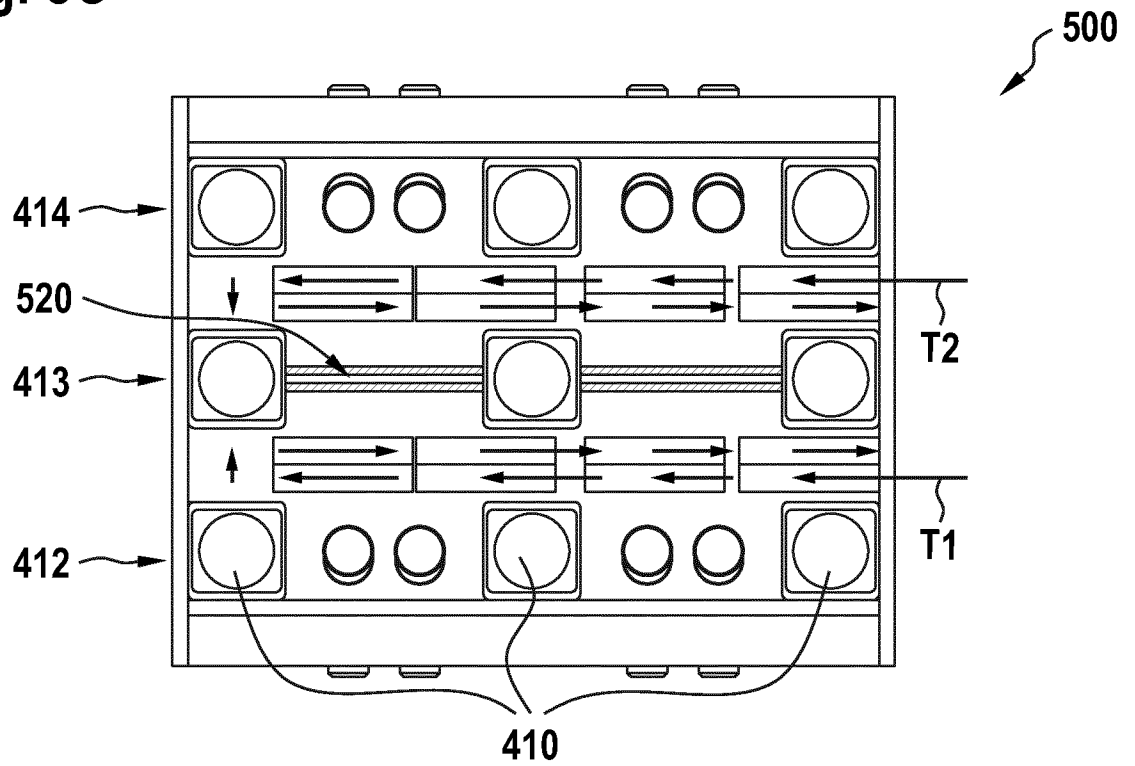
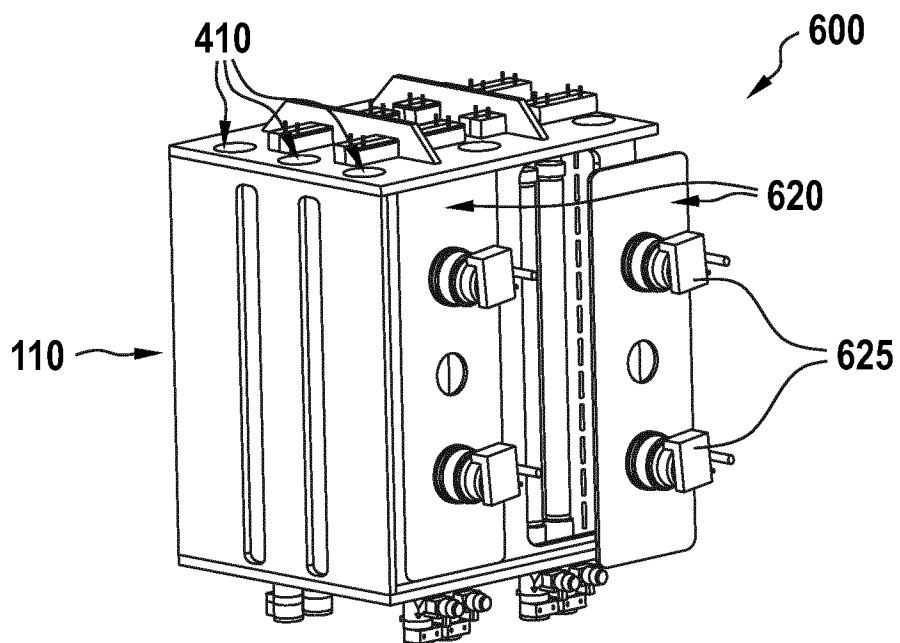


Fig. 6



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Fig. 7

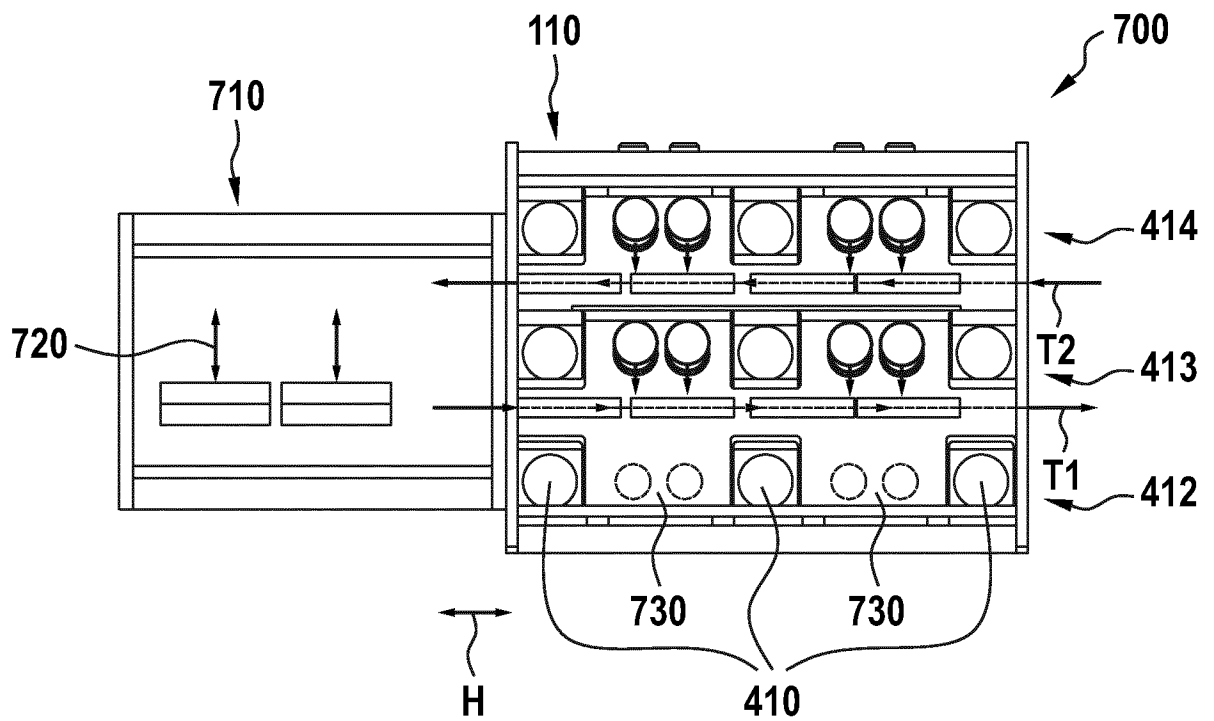
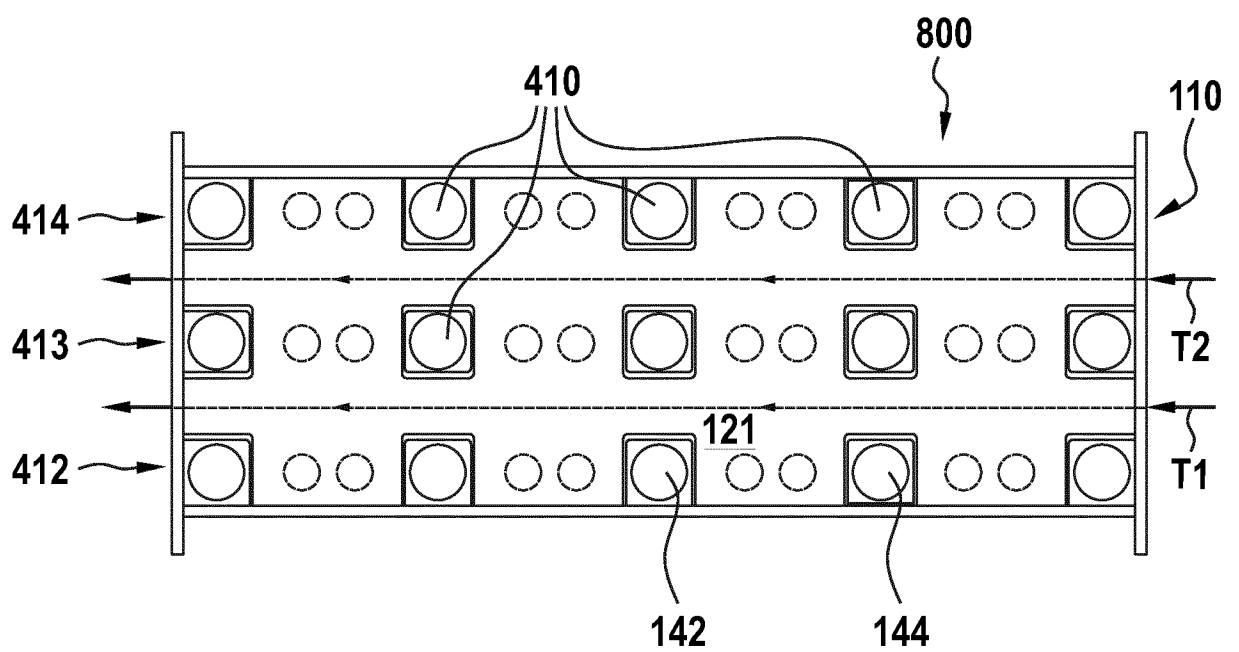


Fig. 8A



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Fig. 8B

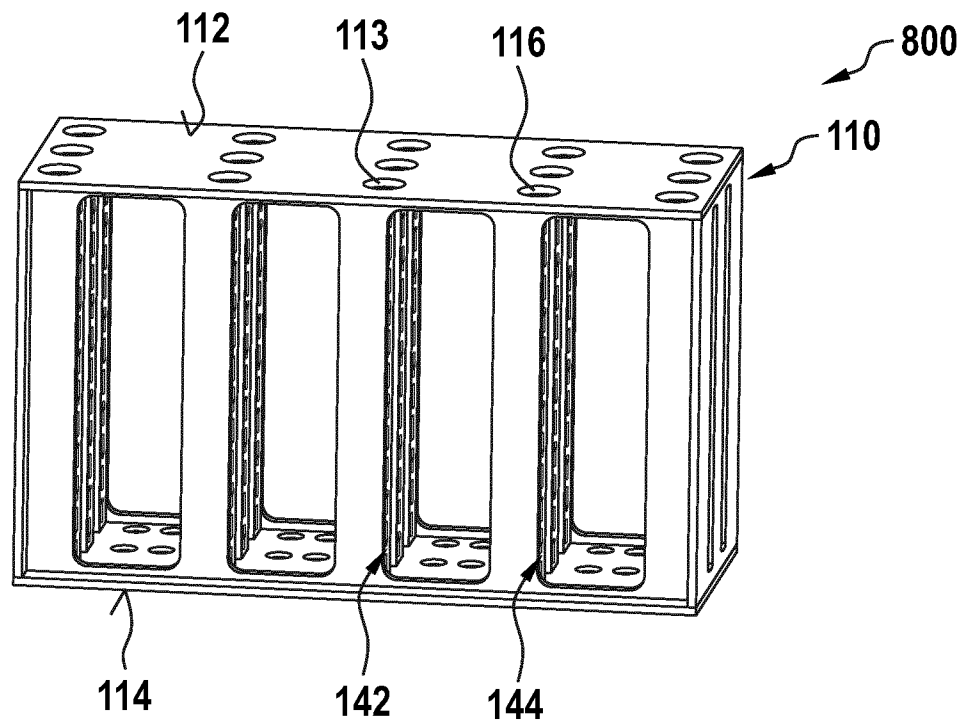
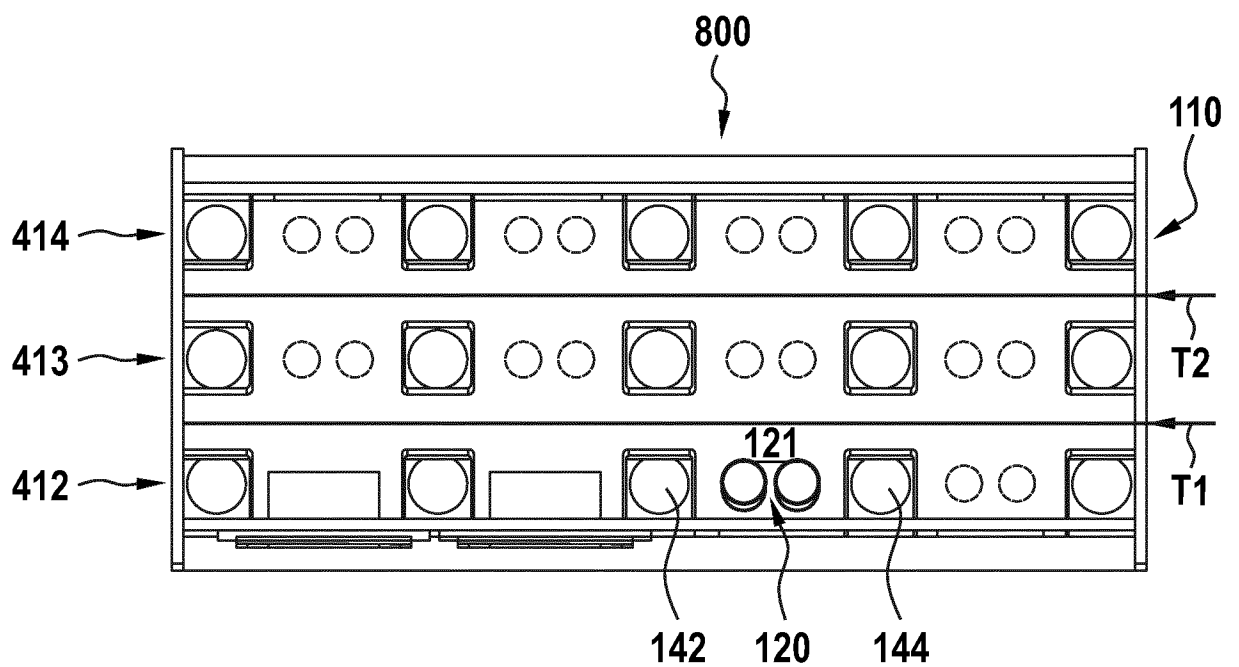


Fig. 8C



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Fig. 8D

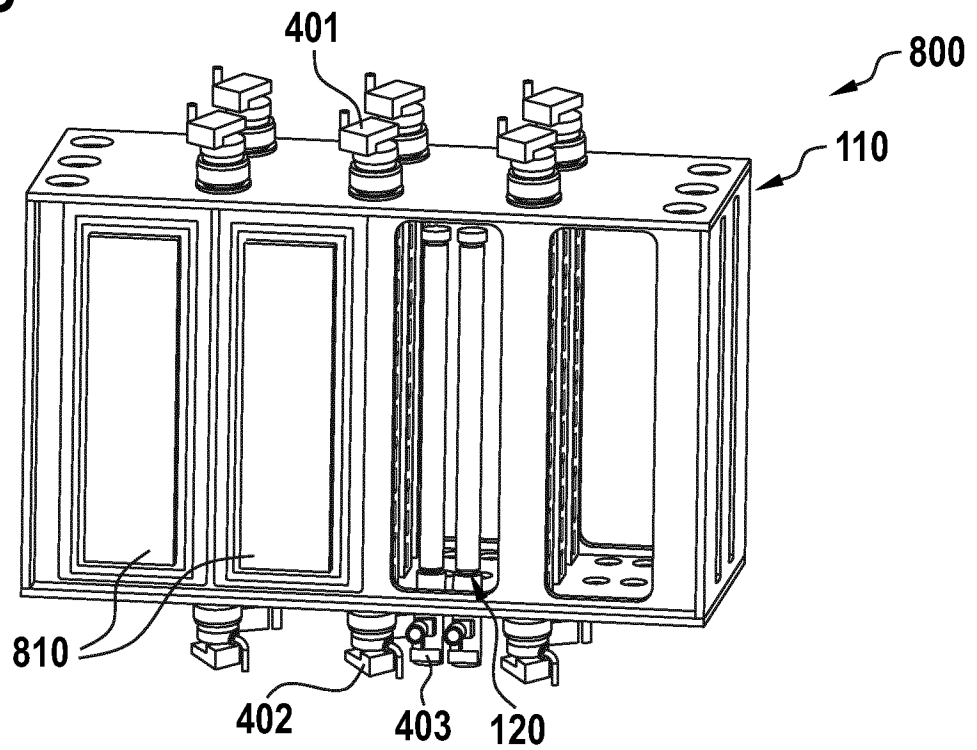


Fig. 9

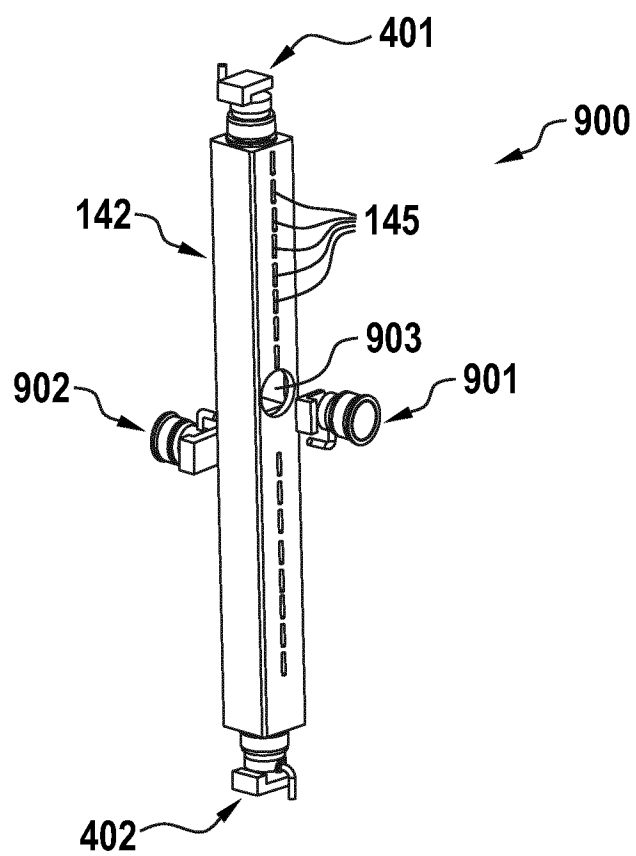


Fig. 10A

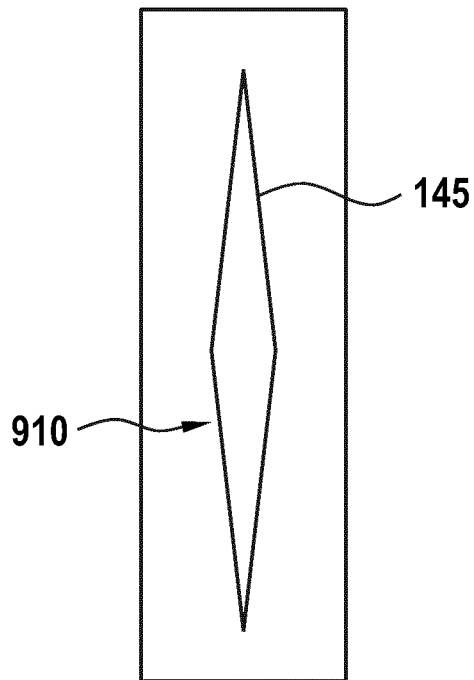


Fig. 10B

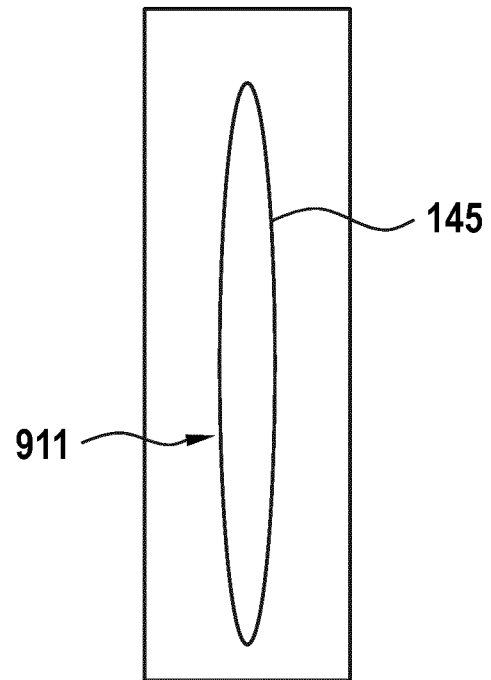


Fig. 10C

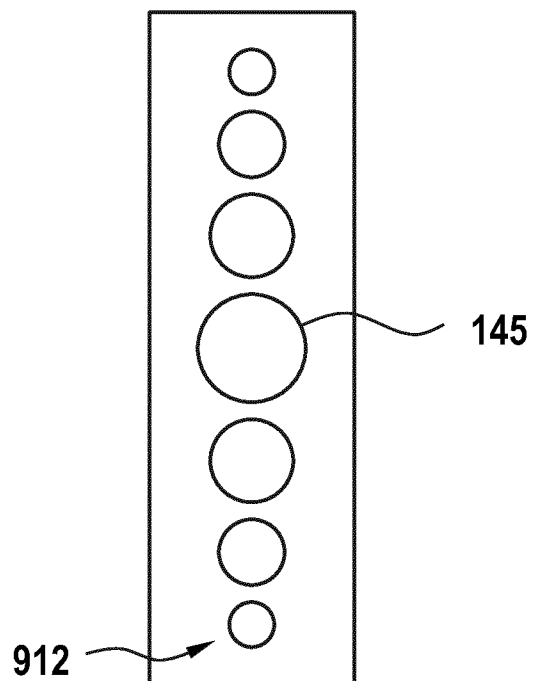
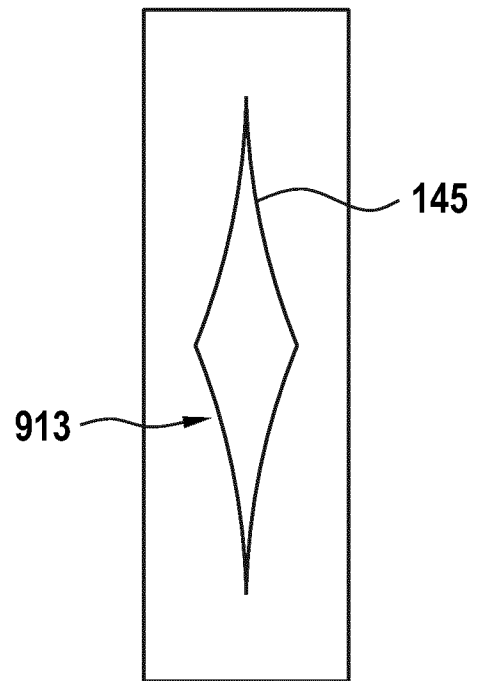
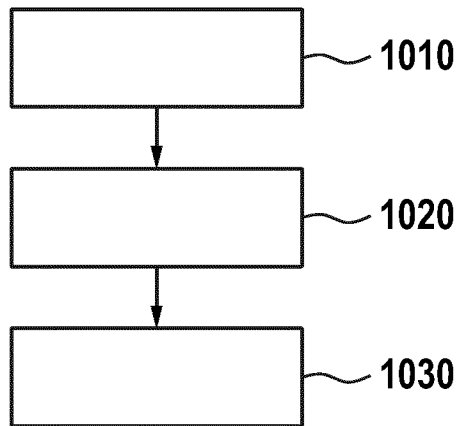


Fig. 10D



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Fig. 11



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/077324

A. CLASSIFICATION OF SUBJECT MATTER
INV. C23C14/34 H01J37/34 C23C16/44 C23C16/455 H01J37/32
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 H01J

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, IBM-TDB

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2011/212625 A1 (TOYODA KAZUYUKI [JP] ET AL) 1 September 2011 (2011-09-01) paragraphs [0071], [0079] - [0081], [0104] - [0109]; figures 10, 11A, 11B -----	1-21
X	JP H01 188674 A (ISHIKAWAJIMA HARIMA HEAVY IND) 27 July 1989 (1989-07-27) Abstract; column 8 - column 13; figures 1-4 -----	1-21
A	US 2013/340681 A1 (WAGNER PHILIPP [CH] ET AL) 26 December 2013 (2013-12-26) paragraphs [0021] - [0024]; figure 2 -----	1-21
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Date of the actual completion of the international search

19 July 2017

Date of mailing of the international search report

31/07/2017

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European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

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Peijzel, Paul

INTERNATIONAL SEARCH REPORT

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PCT/EP2016/077324

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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International application No

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