



(51) International Patent Classification:

C23C 14/56 (2006.01) C23C 14/50 (2006.01)
C23C 14/24 (2006.01)

(21) International Application Number:

PCT/US2016/029690

(22) International Filing Date:

28 April 2016 (28.04.2016)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

62/246,095	25 October 2015 (25.10.2015)	US
62/246,401	26 October 2015 (26.10.2015)	US
62/252,900	9 November 2015 (09.11.2015)	US

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(81) Designated States (unless otherwise indicated, for every
kind of national protection available): AE, AG, AL, AM,
AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY,
BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM,
DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT,
HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR,
KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG,
MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM,
PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC,
SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN,
TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

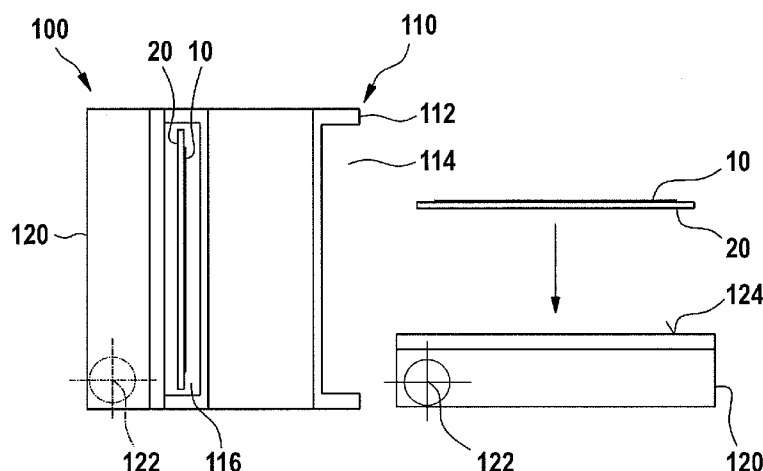
(84) Designated States (unless otherwise indicated, for every
kind of regional protection available): ARIPO (BW, GH,
GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ,
TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU,
TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE,
DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU,
LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK,
SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ,
GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: APPARATUS FOR LOADING A SUBSTRATE, SYSTEM FOR VACUUM PROCESSING OF A SUBSTRATE, AND
METHOD FOR LOADING A SUBSTRATE

Fig. 1A



(57) Abstract: The present disclosure provides an apparatus for loading a substrate in a vacuum processing system. The apparatus includes a vacuum chamber having a housing, an opening in the housing and a door configured for closing the opening. The door is rotatable around a rotational axis to move from a first orientation to a second orientation and vice versa, wherein the door is configured to close the opening in the second orientation. The door is configured to support the substrate when moving from the first orientation to the second orientation to load the substrate into the vacuum chamber.

**APPARATUS FOR LOADING A SUBSTRATE, SYSTEM FOR VACUUM
PROCESSING OF A SUBSTRATE, AND METHOD FOR LOADING A
SUBSTRATE**

FIELD

[0001] Embodiments of the present disclosure relate to an apparatus for loading a substrate in a vacuum processing system, a system configured for vacuum processing of a substrate, and a method for loading a substrate in a vacuum processing system. Embodiments of the present disclosure particularly relate to a combined load lock chamber and swing module for loading a substrate or a substrate carrier having the substrate positioned thereon into a vacuum chamber.

BACKGROUND

[0002] Techniques for layer deposition on a substrate include, for example, sputter deposition, thermal evaporation, and chemical vapor deposition. A sputter deposition process can be used to deposit a material layer on the substrate, such as a layer of a conducting material or an insulating material. During the sputter deposition process, a target having a target material to be deposited on the substrate is bombarded with ions generated in a plasma region to dislodge atoms of the target material from a surface of the target. The dislodged atoms can form the material layer on the substrate. In a reactive sputter deposition process, the dislodged atoms can react with a gas in the plasma region, for example, nitrogen or oxygen, to form an oxide, a nitride or an oxynitride of the target material on the substrate.

[0003] Coated materials may be used in several applications and in several technical fields. For instance, an application lies in the field of microelectronics, such as generating semiconductor devices. Also, substrates for displays are often coated by a sputter deposition process. Further applications include insulating panels, substrates with TFT, color filters or the like.

[0004] As an example, in display manufacturing, it is beneficial to reduce manufacturing costs of displays, e.g., for mobile phones, tablet computers, television screens, and the like. A reduction in manufacturing costs can be achieved, for example, by increasing a throughput of a vacuum processing system, such as a sputter deposition system. Further, the footprint can be a relevant factor for reducing the cost of ownership for a vacuum processing system.

[0005] In view of the above, apparatuses, systems and methods that overcome at least some of the problems in the art are beneficial. The present disclosure particularly aims at providing apparatuses, systems and methods that provide for at least one of an increased throughput and a reduced footprint of a vacuum processing system.

SUMMARY

[0006] In light of the above, an apparatus for loading a substrate in a vacuum processing system, a system configured for vacuum processing of a substrate, and a method for loading a substrate in a vacuum processing system are provided. Further aspects, benefits, and features of the present disclosure are apparent from the claims, the description, and the accompanying drawings.

[0007] According to an aspect of the present disclosure, an apparatus for loading a substrate in a vacuum processing system is provided. The apparatus includes a vacuum chamber having a housing, an opening in the housing and a door configured for closing the opening. The door is rotatable around a rotational axis to move from a first orientation to a second orientation and vice versa, wherein the door is configured to close the opening in the second orientation. The door is configured to support the substrate or a substrate carrier having the substrate positioned thereon when moving from the first orientation to the second orientation to load the substrate into the vacuum chamber.

[0008] According to another aspect of the present disclosure, a system for vacuum processing of a substrate is provided. The system includes a processing module configured for layer deposition on the substrate and the apparatus according to the embodiments described herein, wherein the apparatus is connected to the processing module.

[0009] According to yet another aspect of the present disclosure, a method for loading a substrate in a vacuum processing system is provided. The method includes a positioning of the substrate on a door of a vacuum chamber while the door is in a first orientation, and a rotating of the door around a rotational axis to move the door from the first orientation to a second orientation different from the first orientation to load the substrate into the vacuum chamber.

[0010] According to a further aspect of the present disclosure, an apparatus for at least one of loading and unloading a substrate carrier in a vacuum processing system is provided. The apparatus includes a vacuum chamber having an opening and a door configured for closing the opening, wherein the door is configured to support the substrate or a substrate carrier having the substrate positioned thereon during the loading and/or unloading.

[0011] According to a yet further aspect of the present disclosure, an apparatus for loading a substrate in a vacuum processing system is provided. The apparatus includes a vacuum chamber having a housing, an opening in the housing and a door configured for closing the opening. The door is moveable from a first orientation to a second orientation in front of the opening to cover the opening. The apparatus includes one or more magnetic devices at at least one of the housing and the door, wherein the one or more magnetic devices are configured to provide an attractive force acting on the door in the second orientation to seal the opening, and wherein the one or more magnetic devices are configured to provide a repulsive force acting on the door to release the seal.

[0012] Embodiments are also directed at apparatuses for carrying out the disclosed methods and include apparatus parts for performing each described method aspect. These method aspects may be performed by way of hardware components, a computer programmed by appropriate software, by any combination of the two or in any other manner. Furthermore, embodiments according to the disclosure are also directed at methods for operating the described apparatus. The methods for operating the described apparatus include method aspects for carrying out every function of the apparatus.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] 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:

- FIG. 1A shows a schematic side view of an apparatus for loading a substrate in a vacuum processing system according to embodiments described herein;
- FIG. 1B shows a schematic top view of the apparatus of FIG. 1A according to embodiments described herein;
- FIGs. 2A-2C show a sequence of a closing of the door of the apparatus according to embodiments described herein;
- FIG. 3A shows a schematic top view of a system for vacuum processing of a substrate according to embodiments described herein;
- FIG. 3B shows a schematic cross-sectional view of a bi-directional sputter deposition source according to embodiments described herein;
- FIG. 4 shows a schematic side view of a loading and/or unloading procedure of the substrate using a Bernoulli-type holder according to embodiments described herein;
- FIG. 5 shows a flowchart of a method for loading a substrate in a vacuum processing system according to embodiments described herein;
- FIGs. 6A-6F show a sequence of a loading procedure of substrates into the system for vacuum processing according to embodiments described herein; and

FIGs. 7A and 7B show schematic side views of a loading and/or unloading procedure of a pre-treated substrate using a robot according to embodiments described herein.

DETAILED DESCRIPTION OF EMBODIMENTS

[0014] Reference will now be made in detail to the various embodiments of the disclosure, one or more examples of which are illustrated in the figures. Within the following description of the drawings, the same reference numbers refer to same components. Only the differences with respect to individual embodiments are described. Each example is provided by way of explanation of the disclosure and is not meant as a limitation of the disclosure. Further, features illustrated or described as part of one embodiment can be used on or in conjunction with other embodiments to yield yet a further embodiment. It is intended that the description includes such modifications and variations.

[0015] The present disclosure provides a combination of a swing module and a load lock chamber. The swing module can be understood as a module that is configured to rotate or swing to change an orientation of a substrate or a substrate carrier having the substrate positioned thereon, e.g., from vertical to horizontal, and/or vice versa. The door of the load lock chamber carries out the function of the swing module. As an example, the substrate can be moved from an essentially horizontal orientation to an essentially vertical orientation by the rotation of the door while the substrate is simultaneously loaded into the load lock chamber. A throughput of the vacuum processing system can be increased, since two procedures, namely the orientation change and the loading or unloading, can be done at the same time. Further, the footprint of the vacuum processing system can be reduced, since only one module having a minimal volume is provided for performing both the orientation change and the loading/unloading.

[0016] FIG. 1A shows a schematic side view of an apparatus 100 for loading and/or unloading a substrate 10 or a substrate carrier 20 having the substrate 10 positioned thereon in a vacuum processing system according to embodiments described herein. FIG. 1B shows a schematic top view of the apparatus 100 of FIG. 1A. The apparatus 100 can be a load lock chamber configured to be connected to a processing module of the vacuum processing system.

[0017] The apparatus 100 includes a vacuum chamber 110 having a housing 112, an opening 114 in the housing 112 and a door 120 configured for closing the opening 114. The door 120 is rotatable around a rotational axis 122 to move from a first orientation (as shown on the right-hand side of FIG. 1A) to a second orientation (as shown on the left-hand side of FIG. 1A) and vice versa. The door 120 is configured to close the opening 114 in the second orientation. Specifically, the first orientation can correspond to an open position of the door 120, and the second orientation can correspond to a closed position of the door 120. The door 120 is configured to support the substrate 10 and/or the substrate carrier 20 when moving from the first orientation to the second orientation to load the substrate carrier 20 into the vacuum chamber 110. The door 120 can be further configured to support the substrate 10 and/or the substrate carrier 20 when moving from the second orientation to the first orientation to unload the substrate carrier 20 from the vacuum chamber 110.

[0018] Although the example of FIGs. 1A and B shows two vacuum chambers (i.e., two load lock chambers) which are combined back-to-back for illustration of the first orientation and the second orientation of the door 120, it is to be understood that the present disclosure is not limited thereto, and that only one vacuum chamber (i.e., one load lock chamber) can be provided.

[0019] The apparatus 100 provides a combination of a swing module and a load lock chamber. In particular, the swing module doubles as the door of the load lock chamber. Fewer mechanisms such as mechanically moving elements can be provided. A particle generation and a contamination of substrates can be reduced or even avoided. The vacuum processing system, and specifically the minimum-volume load lock chamber of the vacuum processing system provided by the apparatus 100, has a smaller footprint. The minimum-volume load lock chambers allow for a high throughput with slower pumping and venting, i.e., less turbulence. For example, fewer particles are stirred up that could contaminate substrates.

[0020] According to some embodiments, which can be combined with other embodiments described herein, the door 120 includes a support surface 124 configured to support the substrate 10 or the substrate carrier 20 having the substrate 10 positioned thereon, for example, during the rotation of the door 120 around the rotational axis 122.

The substrate carrier 20 can be an electrostatic carrier (E-chuck). The door 120 can be configured to secure the substrate carrier 20, for example, on the support surface 124. The apparatus 100 can include one or more holding devices (not shown) configured for holding the substrate carrier 20 at the door 120. The one or more holding devices can include at least one of mechanical, electrostatic, electrodynamic (van der Waals), and electromagnetic devices. As an example, the one or more holding devices can be mechanical and/or magnetic clamps.

[0021] According to some embodiments, which can be combined with other embodiments described herein, the rotational axis 122 of the rotation is a substantially horizontal rotational axis. The rotation around the rotational axis 122 between the first orientation and the second orientation can be a rotation in a range of 80° to 110° , specifically in a range of 85° to 95° , and can particularly be a rotation by about 90° . In some implementations, the first orientation is a substantially horizontal orientation and/or the second orientation is a substantially vertical orientation. Specifically, the support surface 124 of the door 120 can be a substantially horizontally oriented surface when the door 120 is in the first orientation, and can be a substantially vertically oriented surface when the door 120 is in the second orientation. According to some embodiments, the rotational axis 122 can be provided at an end portion or edge portion of the door 120 such that the door 120 can be brought into an upright position when moving from the first orientation to the second orientation.

[0022] The term “vertical direction” or “vertical orientation” is understood to distinguish over “horizontal direction” or “horizontal orientation”. That is, the “vertical direction” or “vertical orientation” relates to a substantially vertical orientation e.g. of the door 120, the substrate carrier 20, and/or the substrate 10, wherein a deviation of a few degrees, e.g. up to 10° or even up to 15° , from an exact vertical direction or vertical orientation is still considered as a “substantially vertical direction” or a “substantially vertical orientation”. Likewise, a deviation of a few degrees, e.g. up to 10° or even up to 15° , from an exact horizontal direction or horizontal orientation is still considered as a “substantially horizontal direction” or a “substantially horizontal orientation”. The vertical direction can be substantially parallel to the force of gravity.

[0023] The apparatus 100 can provide functions of a swing module to change an orientation of the substrate 10. According to some embodiments, which can be combined with other embodiments described herein, the substrate is in a substantially vertical orientation, for example, during the vacuum deposition process and/or during transportation of the substrate through the vacuum processing system. When referring to the substrate orientation, “substantially vertical” shall allow 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 support or carrier with some deviation from the vertical orientation might result in a more stable substrate position or a downward facing substrate orientation might reduce particles on the substrate during deposition even better. Yet, the substrate orientation, e.g., during a layer deposition process is considered substantially vertical, which is considered different from the horizontal substrate orientation, which may be considered as horizontal $\pm 20^\circ$ or below.

[0024] The apparatus 100 includes a reception space 116 within the vacuum chamber 110. The reception space 116 is accessible through the opening 114 and is configured to receive or accommodate the substrate carrier 20 when the door 120 is in the second orientation. According to some embodiments, the apparatus 100, and specifically the reception space 116, can include a transfer opening 118. The transfer opening 118 is configured for transferring the substrate carrier 20 from the apparatus 100 into, for example, a processing module of the vacuum processing system, and for transferring the substrate carrier 20 from the processing module into the apparatus 100. In particular, the apparatus 100 can be connected to the processing module of the vacuum processing system such that a substrate exchange between the processing module and the apparatus 100 can be conducted under vacuum conditions. A valve, such as a gate valve, can be provided to close the transfer opening 118 substantially vacuum-tight. In one or more directions, a minimal distance between a wall of the vacuum chamber 110 and the substrate carrier 20 can be 50 cm or smaller.

[0025] According to some embodiments, the door 120 is configured to provide a substantially vacuum-tight sealing of the opening 114. In particular, the door 120 can cover the opening 114 such that the vacuum state can be maintained within the vacuum chamber 110, and specifically within the reception space 116. An example, a mechanical contact

between the door 120 and the housing 112 can provide for the substantially vacuum-tight sealing. The mechanical contact between the door 120 and the housing 112 can be established, for example, using one or more magnetic devices as described with respect to FIGs. 2A-C. In some implementations, a sealing device can be provided, for example, between the door 120 and the housing 112. The sealing device can include at least one of an O-ring, a flat elastomer gasket, and vacuum grease.

[0026] According to some embodiments, which can be combined with other embodiments described herein, the apparatus 100 includes a magnetic levitation system for supporting the substrate carrier 20 in the apparatus 100 without contact, i.e., without mechanical contact.

[0027] In some implementations, the substrate carrier 20 includes, or is, an electrostatic chuck (E-chuck). The E-chuck can have a supporting surface for supporting the substrate thereon. In one embodiment, the E-chuck includes a dielectric body having electrodes embedded therein. The dielectric body can be fabricated from a dielectric material, preferably a high thermal conductivity dielectric material such as pyrolytic boron nitride, aluminum nitride, silicon nitride, alumina or an equivalent material; or the dielectric body may be fabricated from a very thin but less thermally-conductive material such as polyimide. The electrodes may be coupled to a power source which provides power to the electrodes to control a chucking force. The chucking force is an electrostatic force acting on the substrate to fix the substrate on the supporting surface.

[0028] In some implementations, the substrate carrier 20 includes, or is, an electrodynamic chuck or Gecko chuck (G-chuck). The G-chuck can have a supporting surface for supporting the substrate thereon. The chucking force is an electrodynamic force acting on the substrate 10 to fix the substrate 10 on the supporting surface.

[0029] FIGs. 2A-C show a sequence of a closing of the door 120 of the apparatus 100 for loading the substrate carrier 20 in a vacuum processing system according to embodiments described herein.

[0030] Referring to FIG. 2A, the door 120 is the first orientation, which is a substantially horizontal orientation. The substrate carrier 20 having the substrate 10 positioned thereon

is located on the door 120, particularly on the support surface provided by the door 120. The substrate carrier 20 can be fixed to the door 120 using one or more holding devices including, but not limited to, mechanical, electrostatic, electrodynamic (van der Waals), and/or electromagnetic devices.

[0031] As indicated with arrow 2, the door 120 is rotated around the rotational axis 122 from the first orientation to the second orientation, which can be a substantially vertical orientation of the door 120. The door 120 provides the function of a swing module for moving the substrate carrier 20 from a horizontal position into an upright (vertical) position.

[0032] According to some embodiments, which can be combined with other embodiments described herein, the door 120 is configured for a translational movement in the second orientation as it is indicated with arrow 3. As an example, after the rotation from the first orientation in the second orientation, the door 120 can be spaced apart from the housing 112. In order to seal the opening 114, the door 120 can perform the translational movement, which can be a substantially horizontal movement, towards the housing 112. The door 120 can mechanically contact the housing 112 so as to seal the opening 114 substantially vacuum-tight as described earlier. The translational movement differs from the rotational movement in that the translational movement does not involve a rotational axis. Instead, the door 120 is displaced or offset in the direction indicated with arrow 3.

[0033] According to some embodiments, which can be combined with other embodiments described herein, the rotational movement around the rotational axis 122 can be a magnetically actuated movement and/or the translational movement can be a magnetically actuated movement. A magnetically actuated movement can be provided by a magnet assembly provided, e.g., within the vacuum chamber 110 or outside the vacuum chamber 110. Providing the magnet assembly outside the vacuum chamber 110 can be beneficial in view of maintenance.

[0034] After the door 120 has been brought into the second orientation, the substrate carrier 20 can be released from the door 120. As an example, a magnetic levitation system can be provided to hold the substrate carrier 20 in a suspended or levitating state within the

vacuum chamber 110 of the apparatus 100, e.g., when the substrate carrier 20 has been released from the door 120. The vacuum chamber 110 of the apparatus 100 can be evacuated in order to generate a technical vacuum inside of the vacuum chamber 110. The substrate carrier 20 having the substrate 10 positioned thereon can then be transferred into a vacuum processing module using, for example, the transfer opening as described with respect to FIGs. 1A and B.

[0035] According to some embodiments, which can be combined with other embodiments described herein, the apparatus 100 includes one or more magnetic devices at at least one of the housing 112 and the door 120. The one or more magnetic devices are configured to provide an attractive force acting on the door 120 in the second orientation to seal the opening 114. In some implementations, the one or more magnetic devices are configured to provide a repulsive force acting on the door 120 to release the seal. The magnetic sealing can reduce a number of mechanically moving elements, reducing the generation of particles in the vacuum processing system, such as the load lock chamber provided by the apparatus 100.

[0036] As an example, one or more first magnetic devices 210 are provided at the door 120 and one or more second magnetic devices 220 are provided at the housing 112. The one or more first magnetic devices 210 can be provided at the circumference portion of the door 120. The one or more second magnetic devices 220 can be provided at the opening 114. Specifically, the one or more first magnetic devices 210 and the one or more second magnetic devices 220 can be provided at corresponding positions when the door 120 is in the second orientation, for example, when the door 120 covers or closes the opening 114. The one or more first magnetic devices 210 and the one or more second magnetic devices 220 can be configured to magnetically interact with each other in order to provide the attractive force and/or the repulsive force.

[0037] In some embodiments, the magnetic sealing provided by the one or more magnetic devices can be configured to seal the opening 114 substantially vacuum-tight. As an example, the door 120 can be moved in front of the opening 114 and at least some of the one or more magnetic devices can be activated to provide the attractive force for pulling the door 120 against the housing 112. A sealing device such as an O-ring can be provided between the door 120 and the housing 112 in order to seal the housing 112 substantially

vacuum-tight. In some implementations, the door 120 can be made of a magnetic material such that the one or more magnetic devices, which can be the one or more second magnetic devices 220 provided at the housing 112, can magnetically interact with the door 120 to provide the attractive force. In further implementations, the magnetic material can be provided on or inside the door 120, e.g., the one or more first magnetic devices 210. The magnetic material can have a reasonably good permeability.

[0038] For releasing the door 120, at least some of the magnetic devices can be deactivated such that the door 120 can be opened. Optionally, at least some of the magnetic devices are configured to provide the repulsive force acting on the door 120 to release the door 120. As an example, an O-ring used as a sealing device can make the housing 112 and the door 120 stick together. The repulsive force can release this connection and allow for an easy opening of the door 120. For the attractive and repulsive force to work, there can be magnets in the door 120 which electromagnetic coils in or on the housing 112 can either push or pull based on the direction of the current through the individual coils.

[0039] According to some embodiments, the one or more magnetic devices include one or more electromagnets, e.g., the above-mentioned electromagnetic coils, provided at the door 120 and/or the housing 112. The one or more electromagnets can be controllable to provide at least one of the attractive force and the repulsive force. Additionally or alternatively, the one or more magnetic devices include one or more magnet units selected from the group consisting of permanent magnets and magnet units made of a magnetic material.

[0040] As an example, the one or more magnetic devices can include one or more electromagnets and one or more magnet units, wherein each electromagnet is configured to magnetically interact with at least one of the one or more magnet units. The one or more electromagnets can be configured to provide a first magnetic field and a second magnetic field having opposite polarities. For instance, the attractive force can be provided between an electromagnet and a corresponding magnet unit when the electromagnet provides the first magnetic field. The repulsive force can be provided between the electromagnet and the corresponding magnet unit when the electromagnet provides the second magnetic field. The one or more electromagnets can be switchable such that the sealing can be established or released.

[0041] According to some embodiments, the one or more magnet units, e.g., the one or more first magnetic devices 210, are provided at the door 120. The one or more electromagnets, e.g., the one or more second magnetic devices 220 can be provided at the housing 112. In further embodiments, the one or more electromagnets, e.g., the one or more first magnetic devices 210, are provided at the door 120. The one or more magnet units, e.g., the one or more second magnetic devices 220 can be provided at the housing 112. In yet further embodiments, at least one electromagnet and at least one magnet unit can be provided at the door 120 and at least one electromagnet and at least one magnet unit can be provided at the housing 112.

[0042] FIG. 3A shows a schematic top view of a system 300 for vacuum processing of a substrate according to embodiments described herein. The system 300 can also be referred to as “vacuum processing system”.

[0043] The system 300 includes a vacuum processing module 301 configured for layer deposition on the substrate and the apparatus 100 according to the embodiments described herein. The apparatus 100, which can be a combined swing module and load lock chamber, is connected to the vacuum processing module 301, for example, via one or more valves, such as a first gate valve 352 and a second gate valve 354. Substrate carriers 20 having the substrate positioned thereon can be transferred between the apparatus 100 and the vacuum processing module 301 via the one or more valves.

[0044] Substrates are locked into the system 300 via the apparatus 100, which is configured as a load lock chamber. FIG. 3A shows a first load lock chamber 101 for the upper portion of a vacuum chamber 310 of the vacuum processing module 301 and a second load lock chamber 102 for the lower portion of the vacuum chamber 310 of the vacuum processing module 301. The apparatus 100 is a combination of a load lock chamber for loading the substrates into the vacuum processing module 301 and a swing module, which changes the orientation of the substrate, for example, from a substantially horizontal orientation to a substantially vertical orientation. According to some embodiments, which can be combined with any other embodiments described herein, the substrates are processed in an essentially vertical orientation within the vacuum processing module 301.

[0045] According to some embodiments, the apparatus 100, and particularly the first load lock chamber 101 and the second load lock chamber 102, can be provided in an enclosure 350 providing a predefined atmospheric condition for the substrates 10 outside of the vacuum within the vacuum processing module 301. For example, a dry air purge can be provided. The enclosure 350 can be configured to provide a clean room environment.

[0046] As exemplarily shown in FIG. 3A, the substrates can be introduced into the enclosure 350 as indicated by arrow 7, for example, using a robot, and can be placed on the substrate carrier 20, which is supported by the door 120 of the apparatus 100. The door 120 of the apparatus 100 can for example be supported by supports 150, which can stand on a floor space when the door 120 is in the open (e.g., horizontal) orientation. Thereafter, the door 120 is rotated around the rotational axis 122. The rotation of the door 120 results in a rotation of the substrate 10 and the substrate carrier 20. Accordingly, the substrate 10 and the substrate carrier 20 “swing” by closing the door 120. After closing of the door 120, the door 120 and the housing 112 form the vacuum chamber 110 of the apparatus 100, which can be evacuated. After the evacuation of the vacuum chamber 110, the valves, such as the first gate valve 352 or the second gate valve 354, can be opened to lock the substrate 10 into the vacuum chamber 310 of the vacuum processing module 301.

[0047] According to some embodiments, which can be combined with other embodiments described herein, the one or more valves, such as the first gate valve 352 or the second gate valve 354, can be magnetic latch lock valves. The magnetic latch lock valve includes a magnetic element at the lock valve door or at the housing 112 of the apparatus 100 opposite to the lock valve door for providing a magnetic force for moving the latch lock valve in a sealed position and/or for removing the latch lock valve out of the sealed position.

[0048] The vacuum processing module 301 includes the vacuum chamber 310 having a first deposition area 314, a second deposition area 314', and a chamber wall. As an example, the chamber wall is a vertical chamber wall of the vacuum chamber 310. In some implementations, the chamber wall can include a first chamber wall 311 adjacent to the first deposition area 314 and a second chamber wall 311' adjacent to the second deposition area 314'. The first chamber wall 311 and the second chamber wall 311' can define boundaries of the vacuum chamber 310, e.g., substantially parallel to a first transport

direction 1 and/or a second transport direction 1' for the substrate carriers 20 past one or more sputter deposition sources. The first chamber wall 311 and the second chamber wall 311', which can be vertical chamber walls, can be substantially parallel to each other.

[0049] The vacuum processing module 301 includes one or more sputter deposition sources, such as one or more bi-directional sputter deposition sources, arranged between the first deposition area 314 and the second deposition area 314'. An exemplary bi-directional sputter deposition source is shown in FIG. 3B. As an example, the first deposition area 314 can be provided at a first side of the one or more sputter deposition sources and the second deposition area 314' can be provided at a second side of the one or more sputter deposition sources opposite the first side. The one or more sputter deposition sources are configured for vacuum deposition on substrates transported in the first transport direction 1 through the first deposition area 314 past the one or more sputter deposition sources and for vacuum deposition on substrates transported in the second transport direction 1' through the second deposition area 314' past the one or more sputter deposition sources. In some implementations, the first transport direction 1 and the second transport direction 1' point in substantially the same direction, for example, parallel to each other. In other implementations, the first transport direction 1 and the second transport direction 1' point in substantially opposite directions. The first transport direction 1 and the second transport direction 1' can be substantially horizontal directions.

[0050] In some implementations, at least one deposition area of the first deposition area 314 and the second deposition area 314' includes a partition provided in a chamber region between the one or more sputter deposition sources and the chamber wall. As an example, a first partition 315 is provided in a chamber region between the one or more sputter deposition sources and the first chamber wall 311. A second partition 315' can be provided in a chamber region between the one or more sputter deposition sources and the second chamber wall 311'. According to some embodiments, the partition, such as the first partition 315 and the second partition 315', can be separation walls, such as vertical walls. As an example, the partition can extend substantially parallel to the chamber wall and/or the respective transport direction, such as the first transport direction 1 and the second transport direction 1'.

[0051] The partition separates the chamber region into the respective deposition area and a transportation area, wherein the transportation area is at least partially shielded from the one or more sputter deposition sources. As an example, the first partition 315 separates the chamber region between the one or more sputter deposition sources and the first chamber wall 311 into the first deposition area 314 and a first transportation area 313. The second partition 315' can separate the chamber region between the one or more sputter deposition sources and the second chamber wall 311' into the second deposition area 314' and a second transportation area 313'. According to some embodiments, which can be combined with other embodiments described herein, the transportation area is configured as at least one of a substrate cooling area and a substrate waiting area. The coated substrates can cool after deposition and/or wait for a load lock chamber to open and/or a path to become clear.

[0052] The vacuum processing module 301 can be configured for substrate transportation along a first transportation path through the respective deposition area and along a second transportation path through the respective transportation area. The transportation area is shielded from the one or more sputter deposition sources and can provide a shielded return path for coated substrates. In particular, the coated substrates can be returned to an original position and can, for example, exit the vacuum chamber 310 through the same gate valve through which the uncoated substrate has entered the vacuum chamber 310. A continuous or quasi-continuous substrate transportation through the vacuum chamber 310 can be provided.

[0053] The vacuum processing module 301 can have two in-line units, such as a first (upper) in-line unit 302 and a second (lower) in-line unit 303, sharing common sputter deposition sources. The first load lock chamber 101 can be connected to the first (upper) in-line unit 302 such that substrate carriers can be exchanged between the first load lock chamber 101 and the first (upper) in-line unit 302, for example, via the first gate valve 352. The second load lock chamber 102 can be connected to the second (lower) in-line unit 303 such that substrate carriers can be exchanged between the second load lock chamber 102 and the second (lower) in-line unit 303, for example, via the second gate valve 354.

[0054] According to some embodiments, which can be combined with other embodiments described herein, the vacuum processing module 301 includes the vacuum chamber 310 having at least a first area, a deposition area, and optionally at least a second

area. The first area and/or the second area extends sufficiently along the transport direction, such as the first transport direction 1 and/or the second transport direction 1', to allow for a movement of the substrate in a direction different from the transport direction past the one or more sputter deposition sources. The direction different from the transport direction past the one or more sputter deposition sources can be substantially transverse or perpendicular to the transport direction (indicated with arrows 4 and 5) within the first area and/or the second area. The term "substantially transverse" is understood particularly when referring to the movement of the substrate in the first area in a direction different from the transport direction, such as the first transport direction 1, to allow for a deviation from the exact transverse or perpendicular movement of $\pm 20^\circ$ or below, e.g. of $\pm 10^\circ$ or below. Yet, the movement of the substrate in the direction different from the transport direction is considered substantially transverse.

[0055] According to some embodiments, which can be combined with other embodiments described herein, the system 300 can be configured as a dual-line system, for example, provided with one single vacuum chamber. As an example, the vacuum processing module 301 has two first areas and two second areas. One first area 312 of the two first areas can be provided adjacent to the first deposition area 314 and the other first area 312' of the two first areas can be provided adjacent to the second deposition area 314'. One second area 316 of the two second areas can be provided adjacent to the first deposition area 314 and the other second area 316' of the two second areas can be provided adjacent to the second deposition area 314'. As an example, the first deposition area 314 can be sandwiched between the one first area 312 and the one second area 316. Likewise, the second deposition area 314' can be sandwiched between the other first area 312' and the other second area 316'.

[0056] The deposition area, such as the first deposition area 314 and/or the second deposition area 314', can have two or more deposition sub-areas each having one or more sputter deposition sources. Each deposition sub-area can be configured for layer deposition of a respective material. The sputter deposition sources in at least some of the deposition sub-areas can be different. In some implementations, at least some of the two or more deposition sub-areas can be configured for deposition of different materials. FIG. 3A shows five sputter deposition sources. The first sputter deposition source 322 can provide a

first material. The second, the third, and the fourth sputter deposition source 324 can provide a second material. The fifth sputter deposition source 326 can provide a third material. For example, the third material can be the same material as the first material. Accordingly, a three layer stack can be provided on the substrate, such as a large area substrate. For example, the first and the third material can be molybdenum and the second material can be aluminum.

[0057] The two or more deposition sub-areas can be separated from each other using deposition separation units 327 (also referred to as “deposition separation shielding”). As an example, deposition separation units 327 can be provided between the sputter deposition sources for providing different materials on the substrate. The deposition separation units 327 can provide for separating a first processing area in the deposition area, such as the first deposition area 314, from a second processing area in the deposition area, wherein the first processing area has a different material deposited as compared to the second processing area. The deposition separation units 327 have an opening configured for allowing a passage of substrates through the opening.

[0058] According to some embodiments, which can be combined with other embodiments described herein, the vacuum processing module 301 of the system 300 provides for a simultaneous processing of two or more substrates using two in-line units in order to increase the throughput. The common sputter deposition sources for a simultaneous deposition of material onto substrates allow for a higher throughput. The simultaneous processing using two in-line units within one vacuum chamber 310 reduces a footprint of the system 300. Particularly for large area substrates, the footprint can be a relevant factor for reducing the cost of ownership for the system 300.

[0059] The substrates, as for example shown in FIG. 3A, have a continuous or quasi-continuous flow along the sputter deposition sources. The substrates can be provided on carriers within the vacuum chamber 310. The substrates enter the vacuum chamber 310 through load locks, which can include a first gate valve 352 configured for access to the first (upper) in-line unit 302 and a second gate valve 354 configured for access to the second (lower) in-line unit 303. The apparatus 100, which can be vented and evacuated, is provided at the gate valves such that the vacuum in the vacuum processing module 301 can be maintained even during the loading and unloading of the substrates.

[0060] The first area(s) and the second area(s) can be track switch areas (first area(s): track switching load/unload; second area(s): track switching return). The first area(s) and the second area(s) are sufficiently long enough to allow for the track switch. The track switch areas can be at each end of the dynamic-deposition zone. This allows for a continuous substrate flow (dynamic deposition) without the need for “run up” and “run away” chamber sections. The in-line processing system has a smaller footprint. The first areas can be separated by a first separation 356. The second areas can be separated by a second separation 358.

[0061] According to some embodiments, one single vacuum chamber, such as the vacuum chamber 310, for deposition of layers therein can be provided. A configuration with one single vacuum chamber having a plurality of areas, such as the first area(s) and the deposition area(s), can be beneficial in an in-line processing system, for example, for dynamic deposition. The one single vacuum chamber with different areas does not include devices for vacuum tight sealing of one area (e.g., the first area(s)) of the vacuum chamber 310 with respect to another area (e.g., the deposition area) of the vacuum chamber 310.

[0062] In some implementations, further chambers can be provided adjacent to the vacuum chamber 310, such as load lock chambers (e.g., the apparatus 100) and/or further processing chambers. The vacuum chamber 310 can be separated from adjacent chambers by a valve, which may have a valve housing and a valve unit

[0063] In some embodiments, an atmosphere in the vacuum chamber 310 can be individually controlled by generating a technical vacuum, for example with vacuum pumps connected to the vacuum chamber 310, and/or by inserting process gases in the deposition area(s) in the vacuum chamber 310. According to some embodiments, process gases can include inert gases such as argon and/or reactive gases such as oxygen, nitrogen, hydrogen and ammonia (NH₃), Ozone (O₃), or the like.

[0064] According to some embodiments, which can be combined with other embodiments described herein, the substrate is in a substantially vertical orientation, for example, during the vacuum deposition process and/or during transportation of the substrate through the vacuum chamber 310. As used throughout the present disclosure,

terms like “vertical direction” or “vertical orientation” are understood to distinguish over “horizontal direction” or “horizontal orientation”.

[0065] According to some embodiments, which can be combined with other embodiments described herein, the system 300 is configured for dynamic sputter deposition on the substrate(s). A dynamic sputter deposition process can be understood as a sputter deposition process in which the substrate is moved through the deposition area along the transport direction while the sputter deposition process is conducted. In other words, the substrate is not stationary during the sputter deposition process.

[0066] In some implementations, the system 300 according to the embodiments described herein is configured for dynamic processing. The system can particularly be an in-line processing system, i.e. a system for dynamic deposition, particularly for dynamic vertical deposition, such as sputtering. An in-line processing system or a dynamic deposition system according to embodiments described herein provides for a uniform processing of the substrate, for example, a large area substrate such as a rectangular glass plate. The processing tools, such as the one or more sputter deposition sources, extend mainly in one direction (e.g., the vertical direction) and the substrate is moved in a second, different direction (e.g., the first transport direction 1 or the second transport direction 1', which can be horizontal directions).

[0067] Apparatuses or systems for dynamic vacuum deposition, such as in-line processing apparatuses or systems, have the advantage that processing uniformity, for example, layer uniformity, in one direction is limited by the ability to move the substrate at a constant speed and to keep the one or more sputter deposition sources stable. The deposition process of an in-line processing apparatus or a dynamic deposition apparatus is determined by the movement of the substrate past the one or more sputter deposition sources. For an in-line processing apparatus, the deposition area or processing area can be an essentially linear area for processing, for example, a large area rectangular substrate. The deposition area can be an area into which deposition material is ejected from the one or more sputter deposition sources for being deposited on the substrate. In contrast thereto, for a stationary processing apparatus, the deposition area or processing area would basically correspond to the area of the substrate.

[0068] In some implementations, a further difference of an in-line processing system, for example, for dynamic deposition, as compared to a stationary processing system can be formulated by the fact that the apparatus can have one single vacuum chamber with different areas, wherein the vacuum chamber does not include devices for vacuum tight sealing of one area of the vacuum chamber with respect to another area of the vacuum chamber. Contrary thereto, a stationary processing system may have a first vacuum chamber and a second vacuum chamber which can be vacuum tight sealed with respect to each other using, for example, valves.

[0069] According to some embodiments, which can be combined with other embodiments described herein, the system 300 includes a magnetic levitation system for holding the substrate carrier 20 in a suspended state. Optionally, the system 300 can use a magnetic drive system configured for moving or conveying the substrate carrier 20 in the transport direction, such as the first transport direction 1. The magnetic drive system can be included in the magnetic levitation system or can be provided as a separate entity.

[0070] The embodiments described herein can be utilized for evaporation on large area substrates, e.g., for display manufacturing. Specifically, the substrates or carriers, for which the structures and methods according to embodiments described herein are provided, are large area substrates. For instance, a large area substrate or carrier 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), 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 x 3.05 m). Even larger generations such as GEN 11 and GEN 12 and corresponding substrate areas can similarly be implemented.

[0071] The term “substrate” as used herein shall particularly embrace inflexible substrates, e.g., glass plates and metal plates. However, the present disclosure is not limited thereto and the term “substrate” can also embrace flexible substrates such as a web or a foil. According to some embodiments, the substrate 10 can be made from any material suitable for material deposition. For instance, the substrate 10 can be made from a material selected from the group consisting of glass (for instance soda-lime glass, borosilicate glass

etc.), metal, polymer, ceramic, compound materials, carbon fiber materials, mica or any other material or combination of materials which can be coated by a deposition process.

[0072] FIG. 3B shows a schematic top view of a sputter deposition source 500 according to embodiments described herein. The sputter deposition source 500 can be referred to as “bi-directional sputter deposition source”. The bi-directional sputter deposition source can be implemented in the apparatuses and systems according to the embodiments described herein.

[0073] The sputter deposition source 500 includes a cylindrical sputter cathode 510 rotatable around a rotational axis, and a magnet assembly 520 configured to provide a first plasma racetrack 530 and a second plasma racetrack 540 on opposite sides of the cylindrical sputter cathode 510. The magnet assembly 520 includes two, three or four magnets, such as a first magnet 522 and a pair of second magnets. The magnets, such as the first magnet 522 and/or the pair of second magnets, can each include a plurality of sub-magnets. As an example, each magnet can consist of a set of sub-magnets.

[0074] The two, three or four magnets, such as the first magnet 522 and the pair of second magnets, are configured for generating both the first plasma racetrack 530 and the second plasma racetrack 540. In other words, each magnet of the first magnet 522 and the pair of second magnets participates in the generation of both plasma racetracks. In some implementations, the magnet assembly 520 is configured to provide the first plasma racetrack 530 and the second plasma racetrack 540 substantially symmetrical with respect to the rotational axis.

[0075] The first magnet 522 and the pair of second magnets each generate substantially identical magnetic fields on both sides of the cylindrical sputter cathode 510. A sputter performance on both sides of the cylindrical sputter cathode 510 can be made essentially the same. In particular, a sputter rate on both sides can be substantially identical, such that characteristics, e.g., a layer thickness, on two simultaneously coated substrates can be substantially the same.

[0076] The rotational axis can be a cylinder axis of the cylindrical sputter cathode 510. The first magnet 522 and the pair of second magnets can be symmetrical with respect to

the rotational axis of the cylindrical sputter cathode 510. In some implementations, the rotational axis of the cylindrical sputter cathode 510 is a substantially vertical rotational axis. “Substantially vertical” is understood particularly when referring to the orientation of the rotational axis, to allow for a deviation from the vertical direction or orientation of $\pm 20^\circ$ or below, e.g. of $\pm 10^\circ$ or below. Yet, the axis orientation is considered substantially vertical, which is considered different from the horizontal orientation.

[0077] The cylindrical sputter cathode 510 includes a cylindrical target and optionally a backing tube. The cylindrical target can be provided on the backing tube, which can be a cylindrical, metallic tube. The cylindrical target provides the material to be deposited on the substrates. Within the cylindrical sputter cathode 510, a space 512 for a cooling medium, for example, water, can be provided.

[0078] The cylindrical sputter cathode 510 is rotatable around the rotational axis. The rotational axis can be the cylinder axis of the cylindrical sputter cathode 510. The term “cylinder” can be understood as having a circular bottom shape and a circular upper shape and a curved surface area or shell connecting the upper circle and the little lower circle. A single magnet set including the first magnet 522 and the pair of second magnets is configured for producing the magnetic fields on both (e.g., opposite) sides of the rotary target, for example, both sides of the curved surface area or shell to generate the plasma racetracks.

[0079] The cylindrical sputter cathode 510 having the magnet assembly 520 can provide for magnetron sputtering for deposition of layers. As used herein, “magnetron sputtering” refers to sputtering performed using a magnetron, i.e. the magnet assembly 520, that is, a unit capable of generating a magnetic field. The magnet assembly 520 is arranged such that the free electrons are trapped within the generated magnetic field. The magnetic field provides the plasma racetracks on the target surface. The term “plasma racetrack” as used throughout the present disclosure can be understood in the sense of electron traps or magnetic-field electron traps provided at or near the target surface. In particular, magnetic field lines penetrating the cylindrical sputter cathode 510 lead to a confinement of electrons in front of the target surface so that due to the high concentration of electrons, a large number of ions and therefore a plasma is produced. The plasma racetracks can also be referred to as “plasma zones”.

[0080] The plasma racetracks of the present disclosure are distinguished from racetrack grooves, which can occur when using planar magnetrons. The presence of a racetrack groove limits a target consumption. When using a rotating cylindrical target, no racetrack groove corresponding to the magnet configuration is formed in the rotating target surface. As a result, a high target material utilization can be achieved.

[0081] During sputtering, the cylindrical sputter cathode 510 and the target are rotated around the magnet assembly 520 including the first magnet 522 and the pair of second magnets, such as a first magnet unit 524 and a second magnet unit 526. Specifically, the first magnet unit 524 and the second magnet unit 526 form the pair of second magnets. The first plasma racetrack 530 and the second plasma racetrack 540 sweep over the surface of the target while the cylindrical sputter cathode 510 and the target rotate over the magnet assembly 520. The cylindrical sputter cathode 510 and the target rotate below the plasma racetracks.

[0082] According to some embodiments, which can be combined with other embodiments described herein, the sputter deposition source 500 provides for the first plasma racetrack 530 and the second plasma racetrack 540, wherein the second plasma racetrack 540 is essentially on the opposite side of the cylindrical sputter cathode 510, i.e., on an opposite side of the cylindrical sputter cathode 510. In particular, the first plasma racetrack 530 and the second plasma racetrack 540 are symmetrically provided on two opposing sides of the cylindrical sputter cathode 510.

[0083] A plasma racetrack, such as the first plasma racetrack 530 or the second plasma racetrack 540, can form one single plasma zone. Even though FIG. 3B shows two portions of each of the first plasma racetrack 530 and the second plasma racetracks 540, the two portions of the respective racetrack are connected with curved or pointed portions at the end of the racetrack to form a single plasma zone or a single plasma racetrack. Accordingly, FIG. 3B shows two plasma racetracks.

[0084] The plasma racetracks are formed by one magnet assembly 520 having the first magnet 522 and a pair of second magnets. Accordingly, the first magnet 522 is involved in the generation of the first plasma racetrack 530 and the second plasma racetrack 540. Similarly, the pair of second magnets is also involved in the generation of the first plasma

racetrack 530 and the second plasma racetrack 540. The first magnet 522 and the magnet units of the pair of second magnets can be next to each other, such that the first magnet 522 is between the pair of second magnets. In some implementations, a top portion of the first magnet unit 524 and a top portion of the second magnet unit 526 can be connected to each other with a first connection device, which may be made of a magnetic material. Likewise, a bottom portion of the first magnet unit 524 and a bottom portion of the second magnet unit 526 can be connected to each other with a second connection device, which may be made of a magnetic material.

[0085] According to some embodiments, which can be combined with other embodiments described herein, the first magnet 522 has a first magnetic pole in the direction of the first plasma racetrack 530 and a second magnetic pole in the direction of the second plasma racetrack 540. The first magnetic pole can be a magnetic south pole and the second magnetic pole can be a magnetic north pole. In other embodiments, the first magnetic pole can be a magnetic north pole and the second magnetic pole can be a magnetic south pole. The pair of second magnets can have the second magnetic poles (e.g., south poles or north poles) in the direction of the first plasma racetrack 530 and the first magnetic poles (e.g., north poles or south poles) in the direction of the second plasma racetrack 540.

[0086] Accordingly, three magnets form two magnetrons, one magnetron for generating the first plasma racetrack 530 and one magnetron for generating the second plasma racetrack 540. Sharing magnets for the two plasma racetracks reduces potentially occurring differences in the first plasma racetrack 530 and the second plasma racetrack 540. The arrows 531 show the main direction of material emission from the target upon bombardment of the ions of the plasma in the first plasma racetrack 530. The arrows 541 show the main direction of material emission from the target upon bombardment of the ions of the plasma in the second plasma racetrack 540.

[0087] According to some embodiments, which can be combined with other embodiments described herein, the magnet assembly 520 is stationary in the cylindrical sputter cathode 510. The stationary magnet assembly defines stationary plasma racetracks, such as the first plasma racetrack 530 and the second plasma racetrack 540. The stationary plasma racetracks can face respective substrates. The term “stationary plasma racetrack” is

to be understood in the sense that the plasma racetrack does not rotate together with the cylindrical sputter cathode 510 around the rotational axis. In particular, the plasma racetrack does not move with respect to the magnet assembly 520.

[0088] In another embodiment, the magnet assembly 520 and therefore plasma racetrack may be rotatable about the cylindrical cathode axis. This additional degree of freedom can be advantageous in terms of, for example, controlling somewhat the angle and distance to the substrate from which the deposited material arrives to the substrate, which can modify the physical and/or electrical properties of the deposited film.

[0089] FIG. 4 shows a schematic side view of a loading and/or unloading of the substrate onto/from a substrate carrier 20 positioned on the door 120 using a handling apparatus 400.

[0090] The handling apparatus 400 includes a Bernoulli-type holder 410 having a surface 412 configured to face the substrate 10, such as a large area substrate, and a gas supply (not shown) configured to direct a stream of gas between the surface 412 and the substrate 10. The Bernoulli-type holder 410 is configured to provide a pressure, e.g., an under-pressure or a reduced pressure, between the substrate 10 and the surface 412 for levitation of the substrate 10. In particular, a gap or space can be provided between the surface 412 and the substrate 10 through which the stream of gas flows. The substrate 10 is levitating based upon the Bernoulli Effect. A pressure is provided between the substrate 10 and the surface 412 for levitation of the substrate 10 to hold the substrate 10 in a levitating or suspended state. The handling apparatus 400 supports the substrate 10 without making (direct) mechanical contact on the face of the substrate. In particular, the substrate 10 floats on a gas cushion. That is, the handling apparatus 400 is contactless on the face of the substrate 10. The terms “reduced pressure” and “under pressure” can be defined with respect to an ambient pressure in which the Bernoulli-type holder 410. In particular, the pressure, such as the reduced pressure or the under pressure, between the substrate 10 and the surface 412 is configured for levitation of the substrate 10. As an example, a difference between the pressure and the ambient pressure is sufficient to compensate for the weight force of the substrate 10.

[0091] The handling apparatus 400 can include the two or more rigid ducts, such as a first rigid duct 420 and a second rigid duct 422 connected to each other with a rotary joint

424. The Bernoulli-type holder 410 can be configured to move substantially vertically, as indicated with arrow 9. As an example, the Bernoulli-type holder 410 can move downwards to put the substrate 10 on the substrate carrier 20 on the door 120 and/or can move upwards for picking up a substrate 10 from the substrate carrier 20 on the door 120. The rotary joint 424 allows for a relative movement between the first rigid duct 420 and the second rigid duct 422 such that the Bernoulli-type holder 410 can move, for example, substantially vertically.

[0092] According to some embodiments, which can be combined with other embodiments described herein, the Bernoulli-type holder 410 further includes one or more safety retainers 460 configured to be positioned below the substrate 10, such as a large area substrate. A gap can be provided between the substrate 10 and the one or more safety retainers 460, in particular when the substrate 10 is in the levitating or suspended state. The one or more safety retainers 460 can also be referred to as “fail-safe substrate retainers”. The one or more safety retainers 460 can retain the substrate 10 in the event of a sudden unexpected loss of gas flow through the Bernoulli-type holder 410. The one or more safety retainers 460 can have contact elements in that case that an emergency contact between the substrate 10 and the one or more safety retainers 460 would occur.

[0093] According to some embodiments, which can be combined with other embodiments described herein, the substrate carriers 20 are supported within the vacuum processing system with a magnetic levitation system. The magnetic levitation system includes first magnets 480 which support the substrate carrier 20 in a hanging position without mechanical contact. The magnetic levitation system provides a levitation, i.e. contactless support, of the substrate carriers. Accordingly, particle generation due to movement of the carriers within the system for dynamic deposition can be reduced or avoided. The magnetic levitation system includes the first magnets 480, which provide a force to the top of the substrate carrier, which is substantially equal to the gravity force. That is, the substrate carriers are hanging contactlessly below the first magnets 480.

[0094] Further, the magnetic levitation system can include second magnets 482, which provide for a translational movement along a transportation direction of the substrate carriers. The substrate carrier 20 can be supported without contact within the system by the

first magnets 480 and moved within the system, e.g., between the apparatus 100 and the vacuum processing module 301, using the second magnets 482.

[0095] FIG. 5 shows a flowchart of a method 550 for loading and/or unloading a substrate or substrate carrier in a vacuum processing system according to embodiments described herein. The method 550 can use the apparatuses and systems according to the embodiments described herein. Likewise, the apparatuses and systems can be configured to implement the method 550.

[0096] The method 550 includes in block 560 a positioning of the substrate on a door of a vacuum chamber or on a substrate carrier positioned on the door while the door is in a first orientation, and in block 570 a rotating of the door around a rotational axis to move the door from the first orientation to a second orientation different from the first orientation to load the substrate into the vacuum chamber. In some implementations, the method 550 includes in block 580 a rotating of the door around the rotational axis from the second orientation to the first orientation to unload the substrate from the vacuum chamber. The method according to the embodiments described herein is further illustrated with respect to FIGs. 6A-F described below.

[0097] According to embodiments described herein, the method for loading a substrate in a vacuum processing system can be conducted using of computer programs, software, computer software products and the interrelated controllers, which can have a CPU, a memory, a user interface, and input and output devices being in communication with the corresponding components of the systems and apparatuses according to the embodiments described herein.

[0098] FIGs. 6A-F show schematic views of a loading procedure of a substrate 10 into a load lock chamber of the system 300 of FIG. 3A using the Bernoulli-type holder 410 described with respect to FIG. 4. In the following, the apparatus for loading a substrate in a vacuum processing system according to the embodiments described herein is referred to as “load lock chamber”.

[0099] The Bernoulli-type holder 410 can be used for loading the substrate 10, such as a large area substrate, on a substrate support surface and/or for unloading the large area

substrate from the substrate support surface. The substrate support surface can be provided by the door 120 of the load lock chamber, or can be provided by a substrate carrier 20, such as an E-chuck, positioned on the door 120. The Bernoulli-type holder 410 can be used for putting the substrate 10 on the door 120, wherein the door 120 is then rotated around a horizontal rotational axis from a first orientation (e.g., a horizontal orientation) to a second orientation (e.g., a vertical orientation) to load the substrate 10 into the load lock chamber. In particular, the rotation of the door 120 can move the substrate 10 and/or the substrate carrier 20 from a horizontal orientation into a vertical orientation. In some implementations, the Bernoulli-type holder 410 is arranged over the door 120 of the load lock chamber in the open position of the door 120.

[00100] A method of loading and/or unloading a substrate 10 in a dynamic deposition system can include at least a loading and holding of a substrate 10 in a Bernoulli-type holder 410, a treating or pre-treating of the substrate 10 in the Bernoulli-type holder 410 using a stream of gas, and a loading of the substrate 10 after the treating, for example, onto the door 120 or the substrate carrier 20 positioned on the door 120. The treatment of the substrate 10 can include at least one of a heating of the substrate 10 and a degassing or outgassing of the substrate 10. The treatment can further include providing at least one of a clean, dry, and chemically-inert environment for the substrate 10.

[00101] The loading and/or unloading in a substrate exchange sequence can use the Bernoulli-type holder 410. This allows substrates to be loaded into/unloaded from the vacuum processing system by a single factory automation robot at the rate of, for example, 60sph while providing for pre-heating/degassing of each substrate before processing.

[00102] In some implementations, the Bernoulli-type holder 410 can be moved in a wait position for conducting the treatment of the substrate 10. As an example, the wait position is above the door 120, which is configured as a rotatable support.

[00103] In FIG. 6A, a robot 610 such as an FE or a front end robot, removes a coated substrate 10', e.g. from lift pins shown above the substrate carrier 20. The Bernoulli-type holder 410 holds another substrate 10, which is preconditioned. The substrate 10 is preconditioned with the Bernoulli-type holder 410 being in a waiting position, for example, above the door 120. For example, the substrate 10 is heated by utilizing the Bernoulli-type

holder 410 with heated gas. Additionally or alternatively, the substrate 10 can be cleaned by utilizing the Bernoulli-type holder 410 with a clean, dry and chemically inert gas, for example nitrogen.

[00104] The pre-treated substrate 10 is put on the substrate carrier 20, for example, by lowering the Bernoulli-type holder 410. In the example shown in FIG. 6B, the substrate 10 is provided on the lift pins above the substrate carrier 20.

[00105] In order to move the Bernoulli-type holder 410, a gas supply 430 for the Bernoulli-type holder 410 can be moved as well. According to some embodiments, which can be combined with other embodiments described herein, the gas, for example nitrogen, provided to the Bernoulli-type holder 410 is provided through the two or more rigid ducts. The two or more rigid ducts can be insulated and/or heated. Further, the two or more rigid ducts can be connected to each other to provide a fluid communication with the rotary joints. The two or more rigid ducts reduce particle generation as compared to other flexible gas supply conduits.

[00106] In FIG. 6C the pre-treated substrate 10 has been located on the lift pins and the robot 610 moves a new, fresh substrate 10'' into the enclosure 350, which is picked up by the Bernoulli-type holder 410. The Bernoulli-type holder 410 supports the fresh substrate 10'' (on the gas cushion, i.e. contactless) and moves upward to the waiting position shown in FIG. 6D, in which the fresh substrate 10'' is pre-treated, for example heated, while other loading and/or unloading procedures take place.

[00107] In FIG. 6E, the pre-treated substrate 10 is lowered on the substrate carrier 20. This can for example be provided by retracting the lift pins such that the substrate 10 is placed on the substrate carrier 20. The substrate 10 can be aligned and/or can be electronically chucked to the substrate carrier 20, which can be an E-chuck.

[00108] As shown in FIG. 6F, the door 120 of the load lock chamber closes with a rotational movement. By closing the door 120 of the load lock chamber, the substrate 10, which is fixed on the substrate carrier 20, is moved from a first orientation, for example essentially horizontally, to a second orientation, for example essentially vertically, to be

processed in the second orientation. The movement includes a rotation around the rotational axis 122, which can be substantially horizontal.

[00109] FIGs. 7A and B show schematic side views of a loading and/or unloading of a pre-treated substrate using a robot according to embodiments described herein.

[00110] The substrate 10 can be located in a treatment apparatus 700 configured for treatment of a substrate 10 for a vacuum deposition process in a vacuum processing module according to embodiments described herein.

[00111] The treatment apparatus 700 can be configured for a treatment or pre-treatment of the substrate 10 using a stream of gas that is directed over at least a portion of the substrate 10. Physical parameters of the gas, such as temperature, humidity, composition, and the like, can be selected for a pre-treatment of the substrate 10 before a vacuum deposition process is conducted on the substrate 10 and/or before the substrate 10 is put on the substrate carrier 20, such as an E-Chuck. The treatment can include an outgassing of the substrate 10 or substrate surface and/or a cleaning of the substrate 10 or substrate surface. In particular, the treatment apparatus 700 can provide a controlled environment for the substrate 10 within a treatment enclosure 710 such that the treatment, e.g., the outgassing or cleaning, can be efficiently conducted.

[00112] According to some embodiments, the treatment apparatus 700 includes the treatment enclosure 710 configured for accommodating a substrate holder 720 and the substrate 10. A gas supply and a gas outlet can be connected to the treatment enclosure 710. Gas can enter the treatment enclosure 710 through the gas supply, can flow through the treatment enclosure 710 along at least one substrate surface, and can exit the treatment enclosure 710 through the gas outlet. The treatment enclosure 710 can provide a substantially sealed or isolated environment for the substrate 10 to provide for improved treatment conditions. In some implementations, the treatment enclosure 710 has at least one opening configured such that the substrate 10 can be inserted into, and removed from, the treatment enclosure 710 through the opening, for example, using a robot 740. According to some embodiments, the opening can be closed at least during the treatment of the substrate 10, for example, using a cover, such as a lid.

[00113] In some implementations, the substrate holder 720 includes one or more posts or pins on which the substrate 10 can rest. The one or more posts or pins can extend substantially vertically. As an example, the one or more posts or pins can be configured to support the backside of the substrate 10. Further, the one or more posts or pins can be configured such that the robot 740, and particularly a robot arm 742 of the robot 740, can pick up the substrate 10 by contacting the substrate surface which also contacts the one or more posts or pins. In some implementations, the one or more posts or pins are retractable. The one or more posts or pins can retract when the robot 740 has engaged the substrate surface such that the substrate 10 can be removed from the treatment enclosure 710, for example, through the opening in the treatment enclosure 710. The robot 740 can load the substrate 10 onto the substrate carrier 20, for example, using retractable pins (not shown) at the substrate carrier 20.

[00114] The present disclosure provides at least some of the following advantages. The present disclosure provides a combination of a swing module and a load lock chamber door. In particular, the door of the load lock chamber carries out the function of a swing module, i.e., the door changes an orientation of the substrate. As an example, the substrate can be moved from an essentially horizontal orientation as presented by all the factory automation robots to an essentially vertical orientation by the rotation of the door while the substrate is simultaneously loaded into the load lock chamber and sealed in by the single action of closing of the door. A throughput of the vacuum processing system can be increased, since three procedures, namely the orientation change, the loading or unloading of the load lock chamber and the elimination of an additional aspect of closing a substrate or carrier access/egress door, can be performed at the same time. Further, the footprint of the vacuum processing system can be reduced, since only one module having a minimal volume is provided for performing, the orientation change, the loading/unloading and closing.

[00115] The load lock chamber having the small volume can easily be vented and evacuated and the gas flow rate for venting and evacuating can be reduced for a given tact time, which reduces particles dislodged from chamber inner surfaces to adhere to a substrate. Accordingly, the distance between walls of load lock chamber and the carrier can be small as compared to other load lock chambers. Additionally, when an E-chuck or G-

chuck is used in conjunction with the above embodiment, even very thin substrates can be most effectively restricted from deforming from a planar condition and the walls may be made even closer still to the substrate and carrier to reduce load lock volume further.

[00116] 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 for loading a substrate in a vacuum processing system, comprising:

a vacuum chamber having a housing, an opening in the housing and a door configured for closing the opening,

wherein the door is rotatable around a rotational axis to move from a first orientation to a second orientation and vice versa, wherein the door is configured to close the opening in the second orientation, and

wherein the door is configured to support the substrate when moving from the first orientation to the second orientation to load the substrate into the vacuum chamber.
2. The apparatus of claim 1, wherein the door is configured to support the substrate when moving from the second orientation to the first orientation to unload the substrate from the vacuum chamber.
3. The apparatus of claim 1 or 2, wherein the rotational axis is a horizontal rotational axis.
4. The apparatus of any one of claims 1 to 3, wherein the first orientation is a horizontal orientation and/or wherein the second orientation is a vertical orientation.
5. The apparatus of any one of claims 1 to 4, wherein a rotation around the rotational axis from the first orientation to the second orientation is a rotation in a range of 80° to 110°.
6. The apparatus of any one of claims 1 to 5, further comprising one or more magnetic devices at at least one of the housing and the door, wherein the one or more magnetic devices are configured to provide an attractive force acting on the door in the second orientation to seal the opening.
7. The apparatus of claim 6, wherein the one or more magnetic devices are configured to provide a repulsive force acting on the door to release the seal.

8. The apparatus of claim 6 or 7, wherein the one or more magnetic devices include one or more electromagnets provided at at least one of the door and the housing, wherein the one or more electromagnets are configured to provide at least one of the attractive force and the repulsive force.
9. The apparatus of any one of claims 6 to 8, wherein the one or more magnetic devices include at least one of one or more permanent magnets and one or more magnet units comprising a magnetic material.
10. The apparatus of any one of claims 1 to 9, wherein the door is further configured for a translational movement in the second orientation.
11. The apparatus of any one of claims 1 to 10, wherein the door is configured to provide a vacuum-tight sealing of the opening.
12. The apparatus of any one of claims 1 to 11, wherein the apparatus is a load lock chamber configured to be connected to a processing module of the vacuum processing system.
13. System for vacuum processing of a substrate, comprising:

a processing module configured for layer deposition on the substrate; and

the apparatus of any one of claims 1 to 12 connected to the processing module.
14. Method for loading a substrate in a vacuum processing system, comprising:

positioning the substrate on a door of a vacuum chamber while the door is in a first orientation; and

rotating the door around a rotational axis to move the door from the first orientation to a second orientation different from the first orientation to load the substrate into the vacuum chamber.
15. The method of claim 14, further comprising:

rotating the door around the rotational axis from the second orientation to the first orientation to unload the substrate from the vacuum chamber.

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Fig. 1A

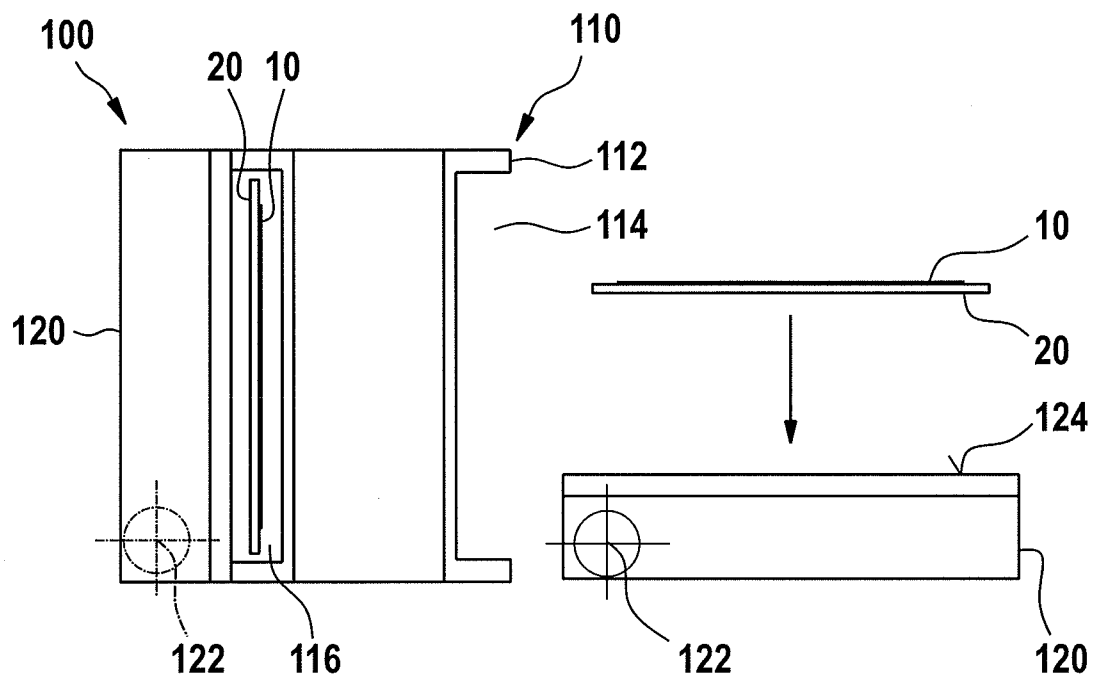
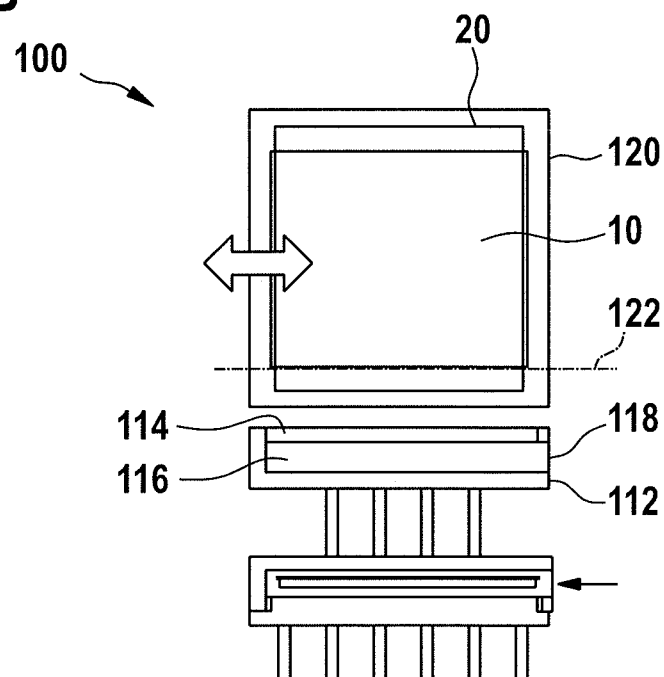


Fig. 1B



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Fig. 2A

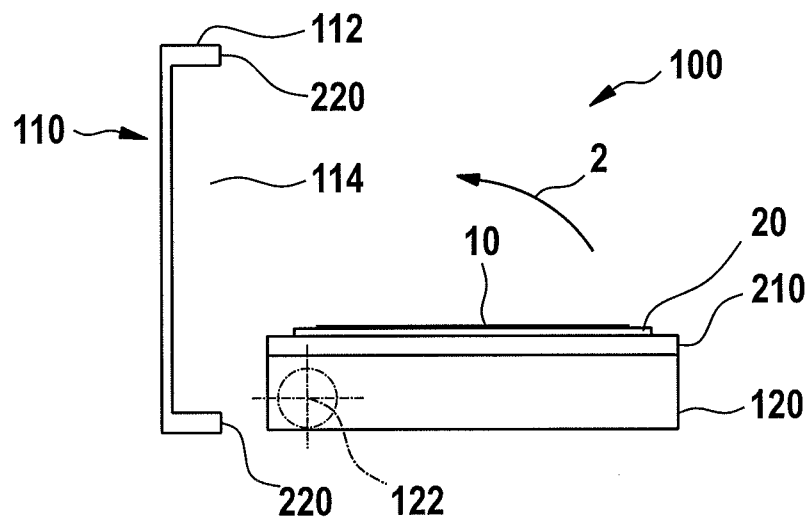


Fig. 2B

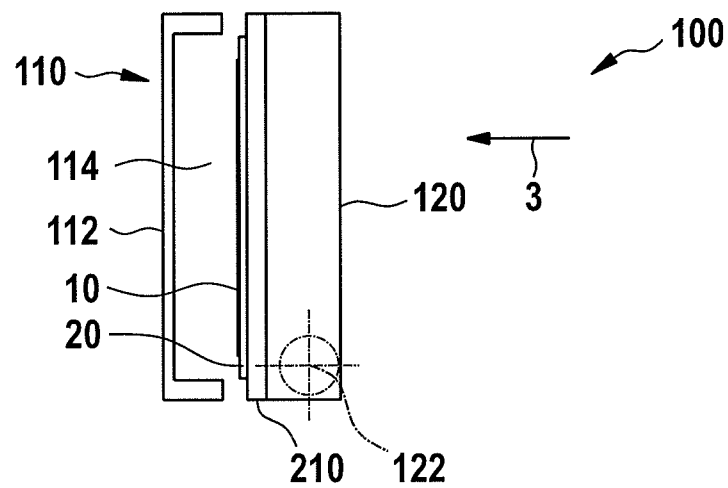


Fig. 2C

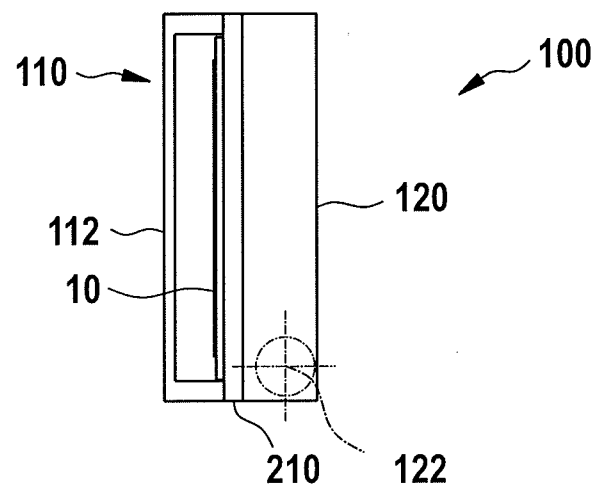
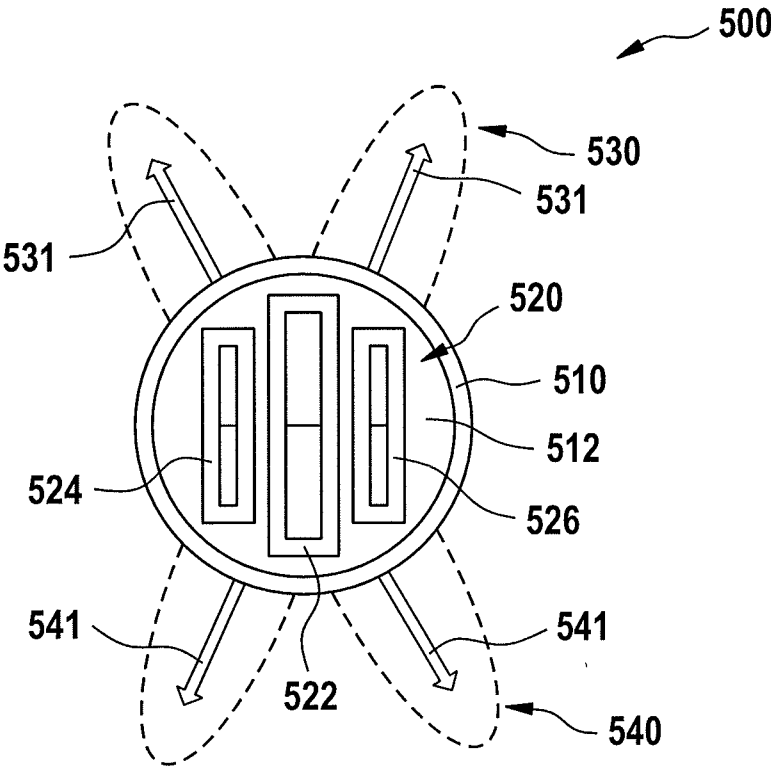


Fig. 3B

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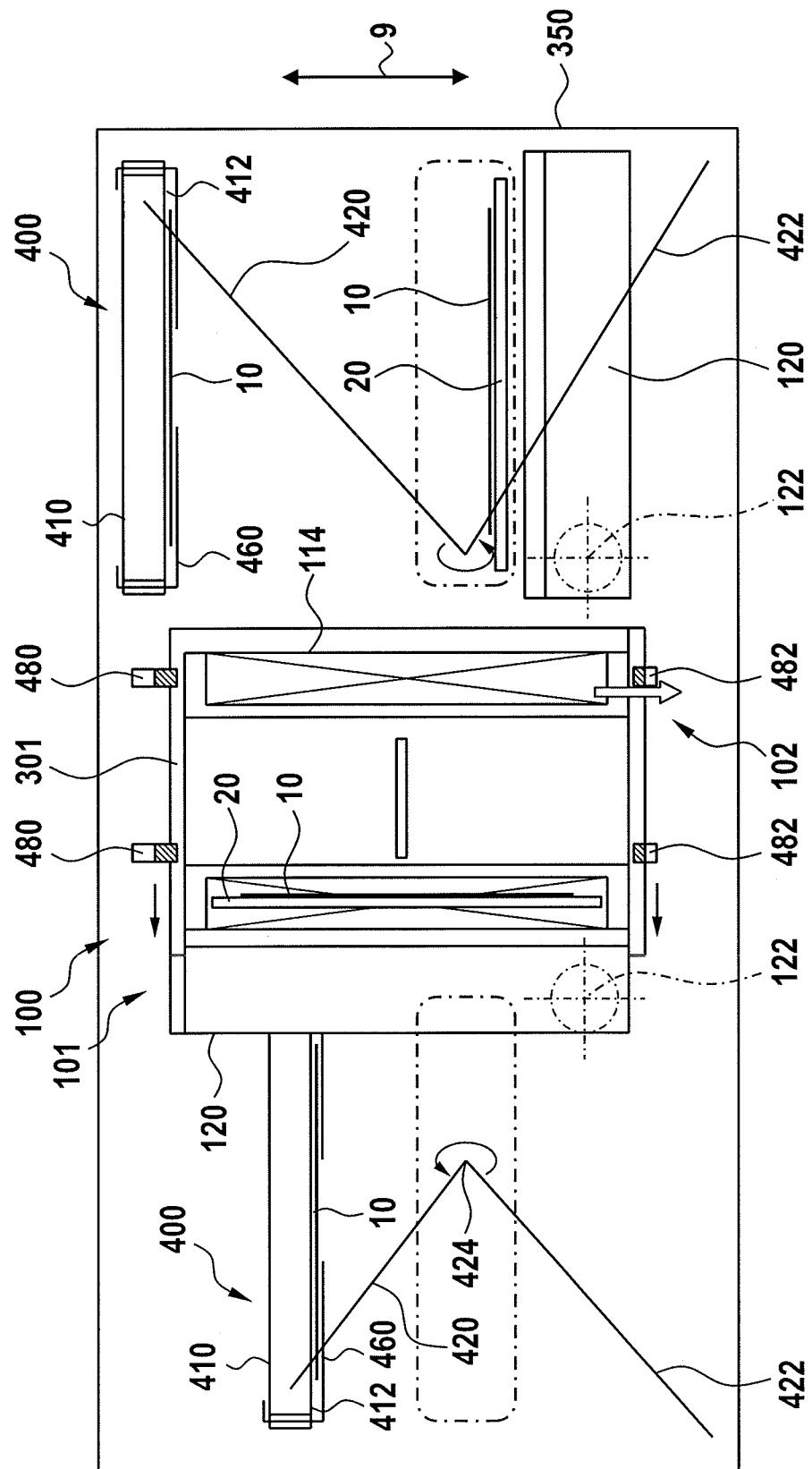
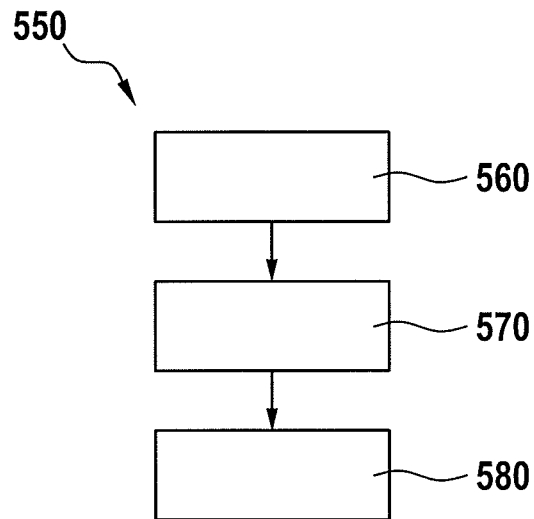


Fig. 4

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Fig. 5



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Fig. 6A

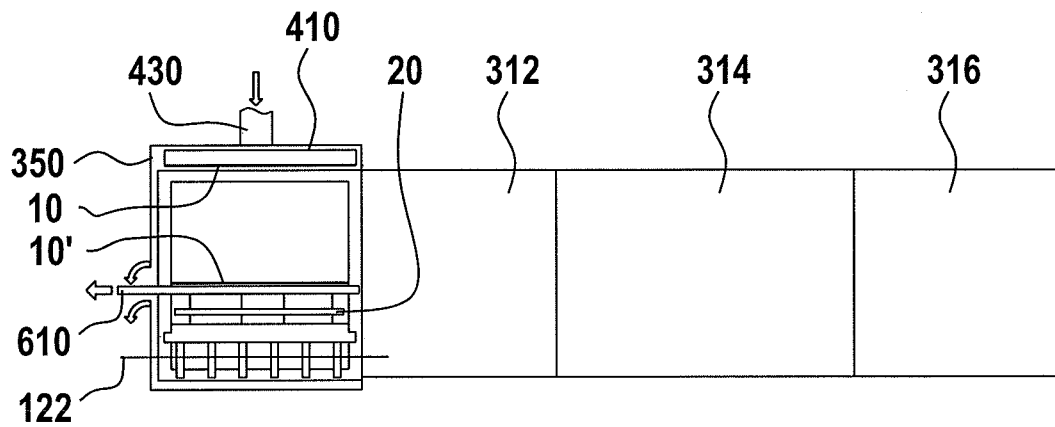


Fig. 6B

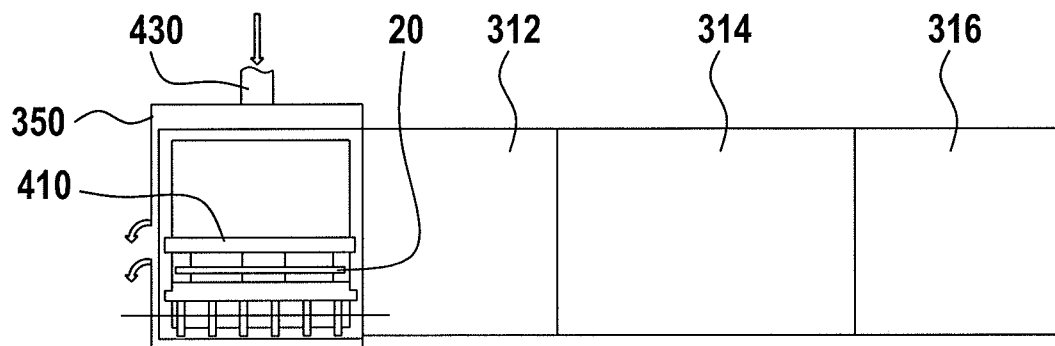
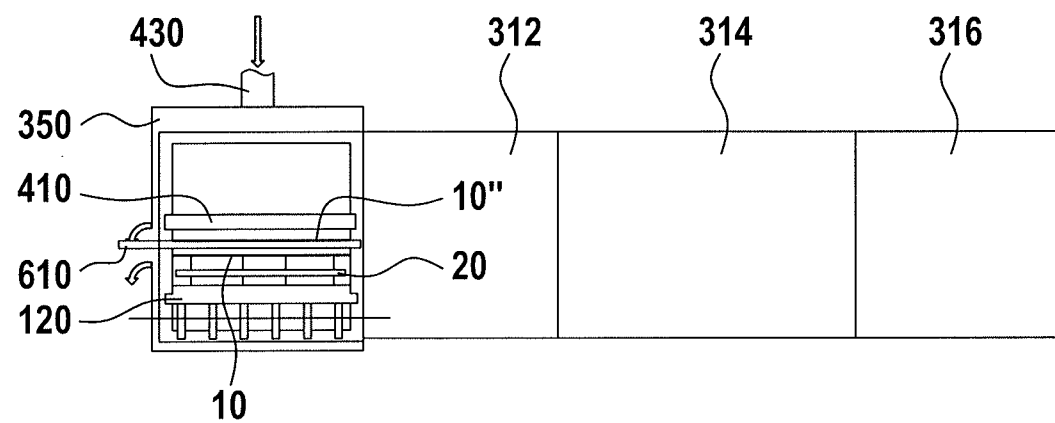


Fig. 6C



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Fig. 6D

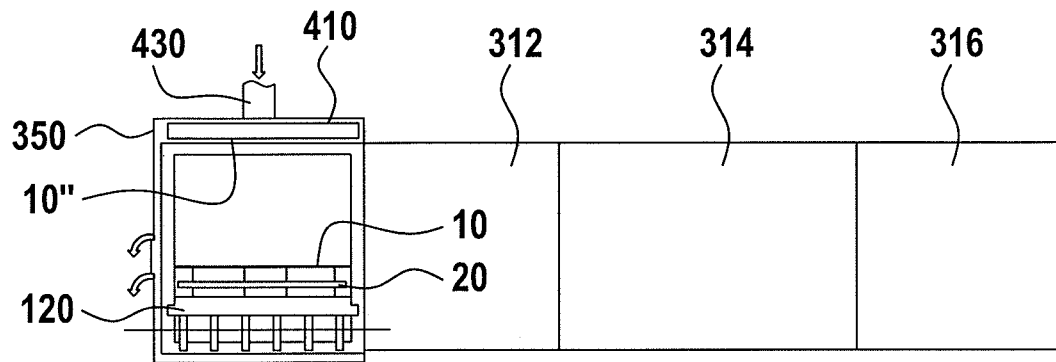


Fig. 6E

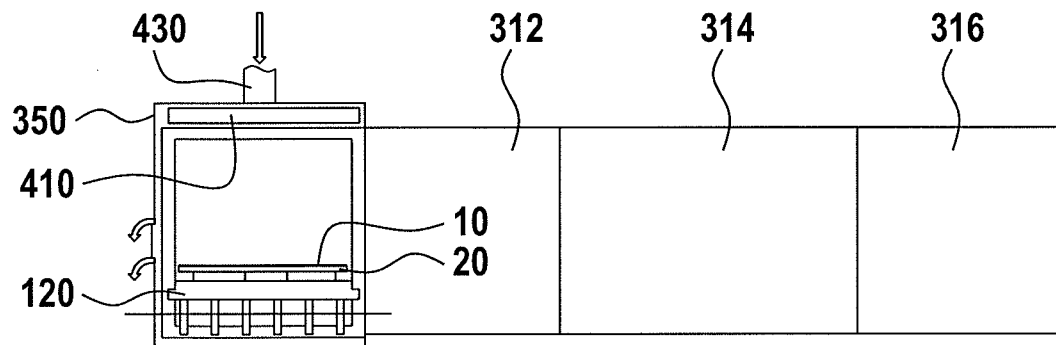


Fig. 6F

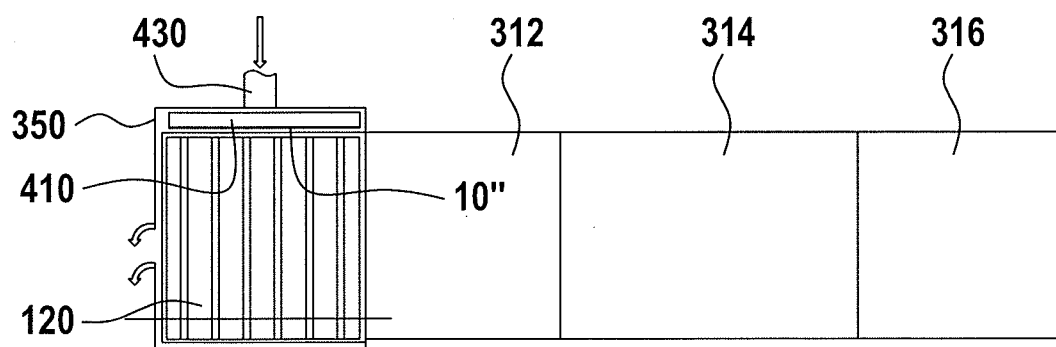


Fig. 7A

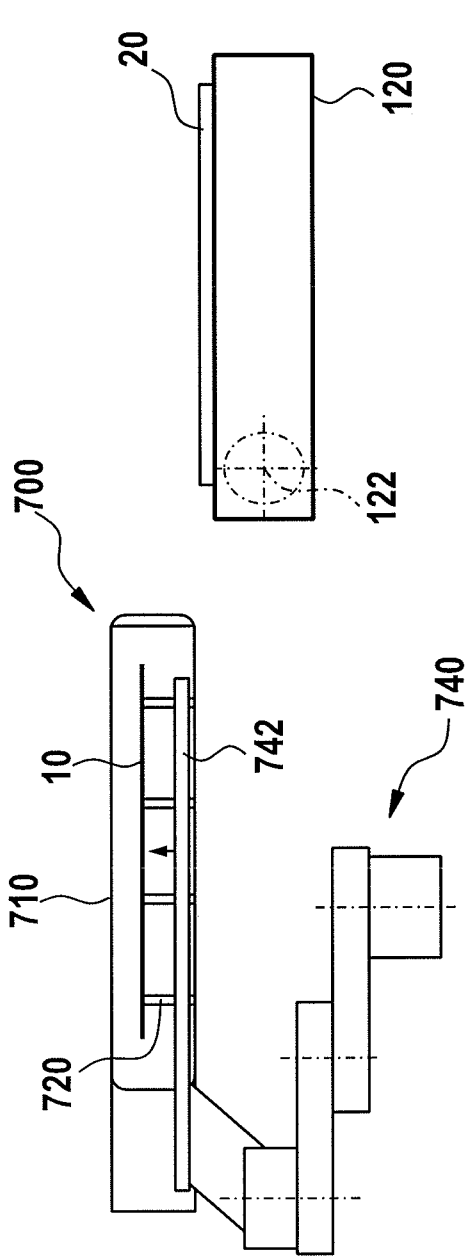
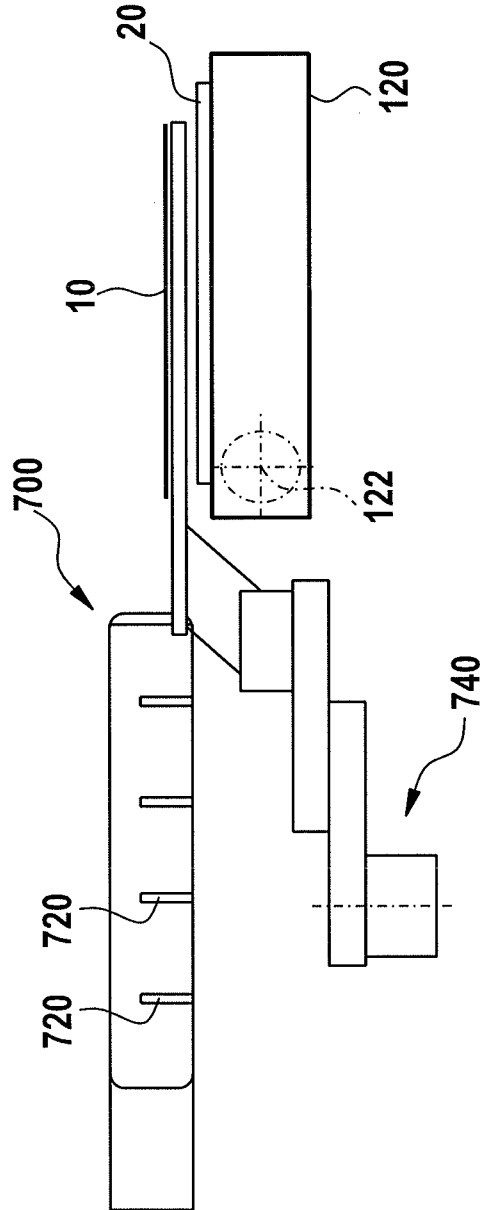


Fig. 7B



A. CLASSIFICATION OF SUBJECT MATTER**C23C 14/56(2006.01)i, C23C 14/24(2006.01)i, C23C 14/50(2006.01)i**

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 14/56; C23C 14/34; B65G 17/08; A47B 96/00; B23P 19/00; C23C 16/509; C23C 16/458; C23C 16/00; C23C 14/24; C23C 14/50

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: vacuum chamber, housing, opening, door, rotation, substrate, and loading

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2012-0091871 A1 (LIM et al.) 19 April 2012 See abstract; paragraphs [0026]-[0028], [0033]-[0035], [0042]-[0046]; claim 1; and figures 3, 4A-4C.	1-3, 14, 15
A	US 6286452 B1 (NAMIKI et al.) 11 September 2001 See abstract; claim 1; and figure 1.	1-3, 14, 15
A	US 5468362 A (MAHLER et al.) 21 November 1995 See abstract; column 2, line 40-column 3, line 33; and figures 1-3.	1-3, 14, 15
A	US 2012-0145079 A1 (LUBOMIRSKY et al.) 14 June 2012 See abstract; paragraphs [0015]-[0017]; claim 1; and figure 1.	1-3, 14, 15
A	US 2001-0014268 A1 (BRYSON, III et al.) 16 August 2001 See abstract; paragraphs [0027]-[0029]; and figure 3.	1-3, 14, 15



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

04 August 2016 (04.08.2016)

Date of mailing of the international search report

04 August 2016 (04.08.2016)

Name and mailing address of the ISA/KR

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INTERNATIONAL SEARCH REPORTInternational application No.
PCT/US2016/029690**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

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

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☒ Claims Nos.: 7
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
Claim 7 refers to multiple dependent claim 6 which does not comply with PCT Rule 6.4(a).
3. ☒ Claims Nos.: 4-6,8-13
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

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

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

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

Remark on Protest

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

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2016/029690

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2012-0091871 A1	19/04/2012	CN 102456597 A CN 102456597 B KR 10-1136728 B1 KR 10-1136729 B1 TW 201232639 A US 8968474 B2	16/05/2012 23/03/2016 20/04/2012 19/04/2012 01/08/2012 03/03/2015
US 6286452 B1	11/09/2001	JP 2000-169961 A	20/06/2000
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US 2012-0145079 A1	14/06/2012	CN 102934214 A CN 102934214 B JP 2013-530536 A KR 10-2013-0087502 A SG 185588 A1 TW 201209880 A US 8524004 B2 WO 2011-159905 A2 WO 2011-159905 A3	13/02/2013 27/01/2016 25/07/2013 06/08/2013 28/12/2012 01/03/2012 03/09/2013 22/12/2011 19/04/2012
US 2001-0014268 A1	16/08/2001	None	