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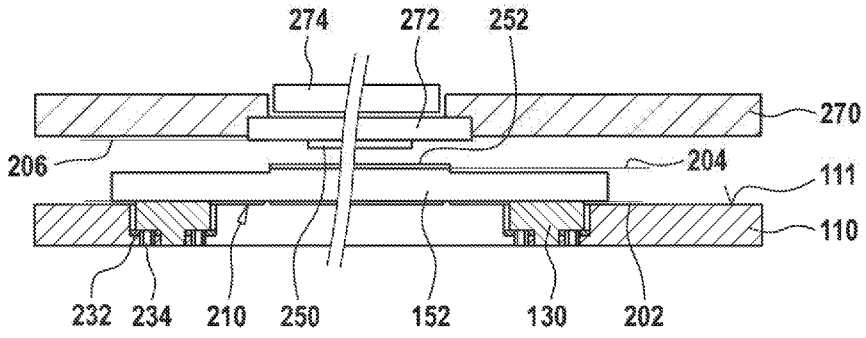
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FIG. 2



(57) Abstract: A carrier for a mask is described. The carrier includes a carrier body having a surface configured to face at least a portion of the mask, the carrier body having an opening for material deposition; and a magnetic holding arrangement having one or more magnetic holders arranged at the carrier body around the opening of the carrier body.

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MASK FRAME INTEGRATION, CARRIER FOR MASK FRAME AND METHOD OF HANDLING A MASK

TECHNICAL FIELD

[0001] Embodiments of the present disclosure relate to mask frame integration for vertical OLED evaporation, methods of handling masks under vacuum in a vacuum system, and particularly to methods of handling masks configured for masked deposition of an evaporated material on substrates in a vacuum system. More specifically, embodiments and implementations of the present disclosure relate to a carrier for a mask, a mask handling module, a method of loading a mask on a mask carrier, and a method of aligning a mask relative to a substrate in a processing chamber.

BACKGROUND

[0002] Opto-electronic devices that make use of organic materials are becoming increasingly popular for a number of reasons. Many of the organic materials used to manufacture such devices are relatively inexpensive, such that organic opto-electronic devices have the potential for cost advantages over inorganic devices. The inherent properties of organic materials may be advantageous for applications such as for the deposition on flexible or inflexible substrates. Examples of organic opto-electronic devices include organic light emitting devices (OLEDs), organic phototransistors, organic photovoltaic cells, and organic photodetectors.

[0003] The organic materials of OLEDS may provide performance advantages over conventional materials. For example, the wavelength at which an organic emissive layer emits light may be readily tuned with appropriate dopants. OLEDs make use of thin, organic films that emit light when a voltage is applied across the device. OLEDs are becoming an increasingly interesting technology for use in applications such as flat panel displays, illumination, and backlighting.

[0004] Materials, particularly organic materials, are typically deposited on a substrate in a vacuum system under sub-atmospheric pressure, i.e. under vacuum. Particularly for RGB (red-green-blue) OLED manufacturing, a mask is arranged in front of the substrate during the deposition, wherein the mask may have at least one opening or a plurality of openings that define an opening pattern corresponding to a material pattern to be deposited on the substrate, e.g. by evaporation. The substrate is typically arranged behind the mask during deposition and is aligned relative to the mask. For example, a mask carrier may be used to carry the mask into a deposition chamber of the vacuum system, and a substrate carrier may be used to carry the substrate into the deposition chamber for arranging the substrate behind the mask.

[0005] OLED display manufacturing has a desire for increasing substrate sizes to reduce manufacturing costs of displays. For RGB (red, green, blue) OLED displays, each pixel includes organic materials for red emission, green emission and blue emission. Accordingly, organic materials emitting the different colors are deposited in patterns, which are to be deposited precisely next to each other on a micron scale. The patterns are generated by, for example, fine metal masks (FFM). Masks typically include a mask frame and a mask sheet having the pattern with a plurality of small openings. In a display manufacturing facility, a mask is typically handled in a horizontal orientation.

[0006] Large area substrates can beneficially be processed in a vertical or essentially vertical orientation. Due to the increasing substrate sizes, the footprint of processing systems can be reduced by vertical processing. Pixel positioning accuracy, particularly on large area substrates, may suffer from changing a mask orientation from a horizontal orientation to a vertical orientation. Considering an alignment in the micron range over a large area of, for example, 1 m^2 or above, gravity acting on the mask including the mask frame and the mask sheet may deteriorate the alignment by changing the mask orientation.

[0007] Accordingly, there is a need for improved mask handling and mask alignment to allow for vertical substrate processing on large area substrates.

SUMMARY

[0008] In light of the above, a carrier for a mask, a mask handling module, a method of loading a mask on a mask carrier, and method of aligning a mask relative to a substrate in a processing chamber are provided. Further aspects, benefits, and features of the present disclosure are apparent from the claims, the description, and the accompanying drawings.

[0009] According to one embodiment, a carrier for a mask is provided. The carrier includes a carrier body having a surface configured to face at least a portion of the mask, the carrier body having an opening for material deposition; and a magnetic holding arrangement having one or more magnetic holders arranged at the carrier body around the opening of the carrier body.

[0010] According to one embodiment, a mask handling module is provided. The mask handling module includes a vacuum chamber; and a power supply configured to provide power to a mask carrier for switching of one or more EPMs within the vacuum chamber.

[0011] According to one embodiment, a mask handling module is provided. The mask handling module includes a vacuum chamber; a support table in the vacuum chamber for supporting the mask carrier, the support table being movable by an angle between a non-vertical orientation, particularly a horizontal orientation, and a non-horizontal orientation, particularly an essentially vertical orientation; an assembly of lift pins configured to support a mask having a mask frame and a mask sheet over the support table; a camera configured to detect a position of the mask distant over the mask carrier and relative to the carrier; and one or more alignment actuators aligning the position of the mask relative to the mask carrier.

[0012] According to one embodiment, a method of loading a mask on a mask carrier is provided. The method includes chucking a mask frame of the mask at a horizontal orientation with a magnetic holding arrangement having the one or more EPMs arranged at the carrier body around an opening of the carrier body.

[0013] According to one embodiment, a method of aligning a mask relative to a substrate in a processing chamber is provided. The method includes supporting the mask with a mask carrier by a magnetic holding arrangement having one or more magnetic holders

arranged at a carrier body of the mask carrier around an opening of the carrier body; supporting the substrate with a substrate carrier; supporting the mask carrier with a mask carrier clamp system, the mask carrier clamp system having one or more first mask carrier clamps and one or more second mask carrier clamps; and moving the one or more second mask carrier clamps relative to the one or more first carrier clamps to deform the mask frame or the mask carrier.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] So that the manner in which the above recited features of the present disclosure can be understood in detail, a more particular description of the present 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. Typical embodiments are depicted in the drawings and are detailed in the description which follows.

[0015] FIG. 1 is a schematic illustration of a mask carrier according to embodiments of the present disclosure provided in a support condition by a magnetic levitation unit;

[0016] FIG. 2 is a schematic illustration of a mask carrier having a mask loaded according to embodiments described herein and further illustrating the relation to a substrate carrier having a substrate;

[0017] FIGS. 3A and 3B are schematic illustrations of operations of a method of loading a mask on a mask carrier according to embodiments described herein;

[0018] FIGS. 4A to 4G are schematic illustrations of operations of a method of handling masks according to embodiments described herein;

[0019] FIGS. 5A to 5D are schematic illustrations of operations of a further method of handling masks according to embodiments described herein;

[0020] FIG. 6A is a schematic illustration of a mask carrier having a mask, a substrate carrier having a substrate, and a mask carrier clamp system, for example, as a portion of an aligner, according to embodiments described herein;

[0021] FIG. 6B is a schematic illustration of a carrier having a magnetic holding arrangement according to embodiments of the present disclosure and exemplarily supporting a mask frame;

[0022] FIG. 7 is a schematic view of a vacuum processing system according to embodiments described herein;

[0023] FIG. 8 is a flow diagram illustrating a method of loading a mask according to embodiments described herein; and

[0024] FIG. 9 is a flow diagram illustrating a method of aligning a mask according to embodiments described herein.

DETAILED DESCRIPTION OF EMBODIMENTS

[0025] Reference will now be made in detail to the various embodiments, one or more examples of which are illustrated in the figures. Each example is provided by way of explanation and is not meant as a limitation. For example, features illustrated or described as part of one embodiment can be used on or in conjunction with any other embodiment to yield yet a further embodiment. It is intended that the present disclosure includes such modifications and variations.

[0026] Within the following description of the drawings, same reference numbers refer to same or to similar components. Generally, only the differences with respect to the individual embodiments are described. Unless specified otherwise, the description of a part or aspect in one embodiment applies to a corresponding part or aspect in another embodiment as well.

[0027] For vertical OLED evaporation, particularly during RGB OLED device manufacturing, a mask for pixel generation of the organic material is provided. A mask

includes a mask frame and a mask sheet, i.e. one or more mask sticks. For example, a fine metal mask (FMM) can be provided. A plurality of openings for pattern generation is provided in the mask sheet. A mask is provided into a processing system generating a plurality of layers of an OLED device at a horizontal orientation, for example, by a handling robot in a manufacturing facility. For vertical OLED evaporation, the mask is flipped from the horizontal orientation to a vertical orientation or an essentially vertical orientation.

[0028] In some embodiments, a mask may include a mask frame and a mask sheet. The mask sheet may be permanently fixed to the mask frame, e.g. by welding, or the sheet may be releasably fixed to the mask frame. The mask may include a plurality of openings formed in a pattern for depositing a corresponding material pattern on a substrate by a masked deposition process. During the deposition, the mask may be arranged at a close distance in front of the substrate or in direct contact with the front surface of the substrate. For example, the mask may be a fine metal mask (FMM) with a plurality of openings, e.g. 100,000 openings, 1,000,000 openings or more. For example, a pattern of organic pixels can be deposited on the substrate. In some embodiments, the mask may be at least partially made of a metal, e.g. of a metal with a small thermal expansion coefficient such as invar. The mask sheet may include a magnetic material so that the mask sheet can be magnetically attracted toward the substrate during deposition. In some embodiments, the mask frame includes a magnetic material so that the mask frame can be attracted to a mask carrier by one or more magnetic holders. The mask may have a surface area of 0.5 m^2 or more, particularly 1 m^2 or more. For example, a height of the mask may be 0.5 m or more, particularly 1 m or more, and/or a width of the mask may be 0.5 m or more, particularly 1 m or more.

[0029] Due to the desired pixel accuracy in the micron range, particularly for large area substrates, the change in orientation changes the influence of gravity and may deteriorate the pixel alignment. One effect is that the change in mask orientation may result in a distortion, bending or bulging of the mask, and particularly the mask frame. For example, a "C-bending" may occur. Another effect is that the change in mask orientation may result in a beam deformation of a beam of the mask frame due to gravity, as such. Embodiments of the present disclosure reduce, prevent, and/or compensate for a combination of such

effects. A mask carrier, a method of loading a mask on a mask carrier, and a method of aligning a mask are provided for mask frame integration for vertical OLED evaporation.

[0030] Embodiments of the present disclosure provide a mask carrier and a method of loading a mask on the mask carrier in an essentially horizontal orientation. The mask carrier is configured to provide a predetermined flatness and stiffness. The mask frame is chucked to the mask carrier with a magnetic holding arrangement to secure the flatness of the mask frame. Counter forces against the mask frame distortion resulting from mask sticks tension and moment of frame weight, particularly upon change of orientation of the mask are provided. According to embodiments of the present disclosure, which can be combined with other embodiments described herein, the mask frame is chucked to the mask carrier in a horizontal orientation, i.e. before a distortion (bending or bulging, such as "C-bending") may occur. A change of the mask orientation towards an essentially vertical orientation is provided after the mask frame has been sufficiently fixed by the magnetic holding arrangement to the stiff mask carrier. Accordingly, a deformation of the mask, e.g. an FMM, can be reduced or prevented.

[0031] FIG. 1 shows a carrier 100 supporting a mask 150. The carrier 100 shown in FIG. 1 is provided under a transferring condition in a vacuum processing system. The carrier is supported by a magnetic levitation system 10. FIG. 2 shows the carrier in a horizontal position. The mask having the mask frame 152 and the mask sheet 252 is, according to embodiments of the present disclosure, loaded on the mask carrier having the carrier body 110 at a horizontal orientation. The substrate carrier 270 supporting the substrate 250 shown in FIG. 2 in a horizontal orientation is shown for illustrative purposes only. As described below exemplarily with respect to FIG. 6A, masking of the substrate 250 with the mask is provided in a processing chamber at a non-horizontal orientation, i.e. a vertical orientation as defined herein.

[0032] As exemplarily shown in FIG. 1, the mask carrier 100 may carry the mask 150 in a non-horizontal orientation during the transport in the processing system and/or during the deposition. For example, the mask 150 may be held by the mask carrier 100 in an essentially vertical orientation during the transport and/or during the deposition.

[0033] A "non-horizontal orientation" of a device as used herein may be an orientation of the device in which an angle between a main surface of the device and a horizontal plane is 45° or more, more particularly 80° or more. An "essentially vertical orientation" of a device as used herein may be understood as an orientation of the device in which an angle between a main surface of the device and the gravity vector is 10° or less. For example, when a mask or a mask carrier is provided in an essentially vertical orientation, an angle between a main surface of the mask or the mask carrier and the gravity vector is 10° or less. In some embodiments, the orientation of the mask may not be (exactly) vertical during transport and/or during deposition, but slightly inclined with respect to the vertical axis, e.g. by an inclination angle between -1° and -5°. A negative angle refers to an orientation of the mask wherein the mask is inclined downward. However, also an exactly vertical orientation (+/-1°) of the mask and the mask carrier during transport and/or during deposition is possible. Reference to a vertical orientation in the present disclosure is understood to have an essentially vertical orientation as described above and distinguishes from, for example, a horizontal orientation. If an exactly vertical orientation (+/-1°) is to be understood, this is referred to as "exactly vertical".

[0034] FIG. 1 shows the mask 150 chucked to the carrier body 110 of the carrier 100. The carrier body 110 has an opening 112. During substrate processing, material to be deposited on a substrate can pass through the opening 112 of the carrier body 110. The mask chucked to the carrier by a magnetic holding arrangement having one or more magnetic holders 130. The one or more magnetic holders 130 are arranged around the opening 112 of the carrier body 110. The magnetic holding arrangement magnetically holds the mask frame 152. The mask frame 152 supports the mask sheet 252 shown, for example, in FIG. 2.

[0035] FIG. 1 further illustrates carrier clamp engaging elements 120 and carrier clamp engaging elements 122. The carrier clamp engaging elements can interact with clamps of the clamp system, for example, a carrier clamp system in a processing chamber.

[0036] Embodiments described herein refer to a carrier for a mask. The carrier includes a carrier body having a surface configured to face at least a portion of the mask, the carrier body having an opening for material deposition. The carrier further includes a magnetic holding arrangement having one or more magnetic holders arranged at the carrier body

around the opening of the carrier body. According to some embodiments, which can be combined with other embodiments described herein, a carrier for a mask can include six or more carrier clamp engaging elements. According to embodiments described herein, a method of loading a mask on a mask carrier includes lowering the mask towards the surface of the carrier body and chucking the mask, particularly the mask frame, with the magnetic holding arrangement in a horizontal orientation.

[0037] FIG. 2 shows the mask carrier body 110. The cross-section of FIG. 2 exemplarily shows two magnetic holders 130. According to some embodiments, which can be combined with other embodiments described herein, the one or more magnetic holders include an electro permanent magnet.

[0038] Electro permanent magnets are beneficial as compared to electromagnets by providing a holding force without applying an electrical current. For an electro permanent magnet, the holding force can be switched on and off. Providing a current to an electro permanent magnet allows to switch between the holding state and a release state. In the holding state, the holding force is switched on. In the release state, the holding force is switched off. Without providing a current, the electro permanent magnet remains in the present state. Accordingly, the mask frame can be securely supported by a magnetic holding arrangement including an electro permanent magnet, for example, without having a power supply connected to the carrier.

[0039] An electropermanent magnet includes a first permanent magnet and at least a second permanent magnet. First permanent magnet and the at least a second permanent magnet are arranged such their adjacent polarities of the first permanent magnet and the at least a second permanent magnet are the same. A core, such as a steel core can be provided between the first permanent magnet and the second permanent magnet. The first permanent magnet and the at least a second permanent magnet could be designated “clamping magnets”, such that the first permanent magnet and the at least a second permanent magnet form a “clamping magnet assembly”. The clamping magnet assembly of an electropermanent magnet element is configured to generate a magnetic field to apply a magnetic holding force.

[0040] A controlling magnet assembly includes at least one controlling magnet being a switchable permanent magnet. When the at least one controlling magnet is polarized in a first polarization, the magnetic field generated by the at least one controlling magnet configures the electropermanent magnet element to be in a non-magnetized state. By switching the polarity of the at least one controlling magnet, the magnetic field generated by the at least one controlling magnet configures the electropermanent magnet element in a magnetized state such that a magnetic holding force is applied.

[0041] An electromagnet may be positioned adjacent to the controlling magnet. The electromagnet is configured to switch the polarity of the at least one controlling magnet. Electromagnet may include at least one coil or at least one winding of an electrically conductive wire. Inducing an electrical current in the at least one coil of electromagnet generates a magnetic field, e.g., a reversing magnetic field. When the reversing magnetic field within the electromagnet exceeds the intrinsic coercivity, or resistance to being demagnetized, of the at least one controlling magnet, the reversing magnetic field causes the polarity of the at least one controlling magnet to switch from a first polarity to a second polarity. Applying electrical current to the coil causes the electropermanent magnet element to switch from a non-magnetized state to a magnetized state and vice versa. After applying the electrical current to the electropermanent magnet element and subsequently removing the electrical current, the configuration of the magnetic field generated by the electropermanent magnet element remains stable. Hence, a electropermanent magnet element exhibits bistable behavior without providing further power to the magnetic holder.

[0042] FIG. 2 shows the carrier body 110 having recesses for the magnetic holders. The carrier body may include one recess per magnetic holder. The magnetic holders 130 can be essentially leveled with a surface 111 of the carrier body. Leveled EPMs can be provided for a magnetic holding arrangement. The surface 111 of the carrier body 110 faces the mask of the mask frame 152, respectively. As indicated by line 202 a lower surface of the mask frame can be parallel to the surface 111 of the carrier body 110. A gap 210 can be provided between the mask frame 152 and the surface 111 of the carrier body. According to some embodiments, which can be combined with other embodiments described herein, the gap can be 0.8 mm or below, such as for example 0.1 mm to 0.2 mm. As compared to the mask having the mask frame and a mask sheet, the carrier having the carrier body is a

heavy and stiff structure. For example, the carrier can have a weight of 200 kg or above. Further, the flatness of the surface 111 of the carrier body 110 can be provided to be 100 μm or below.

[0043] Embodiments of the present disclosure refer to a magnetic holding arrangement having a plurality of magnetic holders such that the flatness of the carrier body can be provided to correspond to a flatness of the mask frame. A reference surface indicated by line 204 of the mask sheet may have a flatness corresponding to the flatness of the mask frame. Due to the stiffness of the mask carrier, the flatness of the mask carrier can be maintained or essentially maintained upon a change of orientation of the mask carrier supporting the mask. The magnetic holding arrangement provided around the opening of the carrier body attaches the mask frame at a plurality of positions to the carrier body. Accordingly, even at a vertical substrate orientation, the magnetic forces acting on the mask frame can simulate gravity acting in a horizontal orientation. The mask frame is sufficiently flat and distortions of the mask frame, bulging of the mask frame, or the like, can be reduced or prevented.

[0044] The magnetic force provided by the magnetic holding arrangement extends over a sufficient portion of the mask frame, for example, along at least 10% of the perimeter or at least 20% of the perimeter of the opening of the carrier body. Additionally or alternatively, at least eight magnetic holders can be provided. As a yet further optional modification at least five magnetic holders can be provided around the opening, which are, optionally, distributed or evenly distributed around the perimeter of the opening.

[0045] According to yet further implementations, which can be combined with various embodiments described herein, one or more height adjustment elements 232 can be provided between the carrier body 110 and the magnetic holders. Height adjustment of the magnetic holders, for example, electro permanent magnets, allows for fine adjustment of the flatness of the mask frame on the surface 111 of the carrier body 110. For example, one or more shims, screws, piezo elements, or other means can be provided for fine adjustment of a magnetic holder 130 relative to the carrier body. For example, an adjustment can be provided with a precision of 30 μm or below, such as from 1 μm to 20 μm.

[0046] Embodiments of the present disclosure allow for clamping of the mask frame, for example, magnetic chucking of the mask frame, to the carrier body. The flatness can be improved to a level of 100 μm or below. Further, friction control elements such as elastic members, for example rubber elements, roughened surfaces, or the like can be provided between the surface of the magnetic holder contacting the mask frame and the mask frame. The mask carrier body and the mask frame can include materials to allow for thermal expansion compliance. For example, the mask carrier body and the mask frame may include materials such that the thermal expansion deviates by less than 10%. For example, the mask carrier body and the mask frame may include the same material.

[0047] As described above, the mask, particularly the mask frame, can be attached to the carrier body in a horizontal orientation with a flatness allowing for the desired pixel positioning accuracy. The magnetic holding arrangement allows for fixing the mask frame to the carrier body at a comparably large area. In order to prevent mask deformation upon movement by an angle from a horizontal to a vertical orientation, the mask carrier stiffness acts against the changing forces due to gravity. According to some embodiments, which can be combined with other embodiments described herein, the mask carrier stiffness is three times or more larger as compared to the mask frame stiffness. Particularly the mask carrier stiffness can be five times or more larger than the mask frame stiffness. The magnetic holding arrangement having, for example, a plurality of electro permanent magnets maintains the same mask frame condition for a vertical orientation as the condition when the mask is assembled to the mask carrier in the horizontal orientation.

[0048] A mask integration, e.g. a FMM integration and a FFM integration structure, particularly with EPMs (Electro Permanent Magnet) at the mask carrier for display OLED evaporation fabrication equipment, is provided. Previous methods attempted to compensate the deformation by the use of an additional adjustment mechanism to counter force against gravity acting on the mask frame and/or to shift the position of FMM sticks on the mask frame by simulating the deformation caused by gravity. Embodiments of the present disclosure may eliminate such additional operations by integrating the mask frame and a mask carrier with a magnetic holding arrangement, wherein the mask carrier has much higher mechanical stiffness. Particularly, distortions of the mask frame can be reduced or prevented. Gravity acting on the mask carrier may be compensated by active elements as

described below. Yet, due to the higher mechanical stiffness of the carrier such mechanical compensation is facilitated.

[0049] FIG. 2 further illustrates the advantages of the increased mask frame flatness. Even though relative positioning of the mask and the substrate is provided in a vertical orientation for vertical OLED manufacturing, FIG. 2 shows the substrate 250 next to the horizontal mask. FIG. 2 shows a carrier 270 having an electrostatic chuck 272. The electrostatic chuck can include a plurality of electrodes generating an electrostatic force for the substrate 250. As indicated by line 206 in FIG. 2 a reference surface of the substrate receiving surface of, for example, the electrostatic chuck, relative to the mask frame and, thus, to the mask sheet can be essentially parallel due to the flatness of the mask. For example, a relative flatness between the mask frame and the substrate receiving surface of the substrate carrier can be 200 μm or below. Upon attracting the mask sheet 252 towards the substrate 250 by the magnet 274 in a deposition condition, for example, after mask-substrate-alignment, the flatness of the reference surface and/or the mask sheet and the substrate being parallel in a range of 200 μm or below allows for good pixel positioning accuracy.

[0050] FIGS. 3A and 3B illustrate a mask carrier 100 and a mask 150 during operation of a method of loading a mask on a mask carrier according to embodiments described herein. FIG. 3A shows a carrier body 110 having an opening 112. A plurality of magnetic holders 130, for example, electro permanent magnets, are provided at the carrier body. The mask frame 152 can be integrated to the carrier body 110 with the magnetic holding arrangement having the magnetic holders. At operation 810 (see FIG. 8) the mask 150 is supported by support pins 330 over the mask carrier 100. The surface 111 of the carrier body faces at least a portion of the mask, particularly the mask frame 152. The mask frame 152 supports the mask sheet 252. FIG. 3A shows a handler 302, for example, arms, of a robot, such as a vacuum robot positioning the mask 150 on the lift pins 330. At operation 820, the mask 150 is lowered towards the surface 111 of the carrier body 110 of the carrier 100. As described above, a predetermined flatness of the mask frame can be provided in the horizontal orientation of the carrier 100. At operation 830, the mask and particularly the mask frame is magnetically chucked to the carrier by the magnetic holding arrangement.

[0051] As shown in FIG. 1, the mask 150 includes the mask frame 152. The mask frame can have a top beam, a bottom beam and side beans connecting the top beam and the bottom beam. The beams can be provided separately or can be integrally formed. A plurality of magnetic holders 130, for example, EPMs, are provided. The order of activating the magnetic holders is from center to edge. Distortion caused by a moment during magnetic chucking at the mask frame can, thus, be reduced. According to some embodiments, which can be combined with other embodiments described herein, a first magnetic holder of the one or more magnetic holders is activated before activating a second holder of the one or more magnetic holders, wherein the first magnetic holder is closer to a mask frame portion center than the second magnetic holder. For example, the mask frame portion can be one of the beams of the mask frame.

[0052] According to some embodiments, which can be combined with other embodiments described herein, the relative position of the mask 150 and the carrier can be adjusted or aligned before chucking of the mask frame to the carrier. For example a camera 360 as shown in FIG. 3B or another vision system can be provided to adjust the position of the mask 150 in the horizontal plane.

[0053] FIGS. 4A to 4G are schematic illustrations of further operations of a method of handling masks according to embodiments described herein. A first mask 450 carried by a mask carrier 410 is unloaded from the mask carrier (see FIGS. 4A to 4D), and subsequently a second mask 452 is loaded on the mask carrier 410 (see FIGS. 4E to 4G). The first mask 450 may be a used mask that is to be unloaded from the vacuum system, e.g. for being cleaned, and the second mask 452 may be a clean mask that is to be transported into a deposition chamber of the vacuum system for being used in an evaporation process.

[0054] FIG. 4A is a schematic view of a mask handling module 20 that is configured to separate the first mask 450 from the mask carrier 410 and to connect the second mask 452 to the mask carrier 410. For example, a mask handling module may according to some embodiments, which can be combined with other embodiments described herein, be provided in a mask loading station. The mask handling module 20 includes a mask carrier support 422 configured to support the mask carrier. In some embodiments, the mask carrier support 422 is movable between an essentially horizontal orientation (H) depicted in FIG.

4A and a non-horizontal orientation, e.g. an essentially vertical orientation. In particular, an actuator may be provided for changing the orientation of the mask carrier support 422 between the non-horizontal orientation and the essentially horizontal orientation.

[0055] As is depicted in FIG. 4A, the mask carrier 410 may be supported on the mask carrier support 422 in the essentially horizontal orientation. For example, the mask carrier may be positioned on top of one or more support sections 421 of the mask carrier support, e.g. after the orientation change to the essentially horizontal orientation. The first mask 450 may be fixed to the mask carrier 410 with the plurality of EPMs. The EPM's can be switched in a non-holding state to detach the first mask 450. Subsequently, the first mask 450 may be lifted up from the mask carrier 410, e.g. with a plurality of lifting pins 330 that are movable relative to the support sections 421 of the mask carrier support 422 in an essentially vertical direction.

[0056] In some embodiments, unloading the first mask 450 from the mask carrier 410 may further include inserting a mask holding portion 432 of a vacuum robot between the lifted first mask and the mask carrier. In particular, the mask holding portion 432 may be inserted in a gap between the mask carrier 410 and the first mask 450, after the first mask has been lifted up by a distance of 50 mm or more, particularly 100 mm or more, from the mask carrier. FIG. 4C shows the mask handling module after the insertion of the mask holding portion 432 of the vacuum robot. The mask holding portion 432 may be a movable robot hand of a vacuum robot, e.g. including one or more plate sections or arm sections for supporting a mask thereon.

[0057] The mask holding portion 432 with the first mask 450 supported thereon may be moved away from the mask carrier 410, e.g. in a vertical direction and/or in a horizontal direction, as is schematically depicted in FIG. 4D. In particular, the mask holding portion 432 may transfer the first mask 450 into a mask holder which may be arranged in a load-lock chamber.

[0058] After unloading the first mask 450 from the mask carrier 410, a second mask 452 may be loaded on the mask carrier, as is schematically depicted in FIG. 4E. Loading the second mask 452 on the mask carrier 410 may include moving the second mask 452 to a position over of the mask carrier 410 with the mask holding portion of the vacuum robot or

with a second mask holding portion 433 of the vacuum robot. For example, the second mask 452 may be transferred by the vacuum robot from a mask shelf provided in a load-lock chamber to a position over the mask carrier 410 while the mask carrier is supported by the mask carrier support 422 in a horizontal orientation.

[0059] As is schematically depicted in FIG. 4E, the second mask 452 may be positioned on lifting pins 330 by lowering the second mask holding portion 433 of the vacuum robot until the second mask 452 comes in contact with and is supported by the lifting pins 330. Subsequently, the lifting pins may be lowered until the second mask 452 is placed on the mask carrier 410.

[0060] In some embodiments, which may be combined with other embodiments described herein, loading the second mask 452 on the mask carrier 410 may further include aligning the second mask 452 with respect to the mask carrier 410, e.g. utilizing an optical alignment system configured to align the second mask 452 relative to the mask carrier 410 in two transverse horizontal directions. The alignment of the second mask relative to the mask carrier is schematically depicted in FIG. 4F.

[0061] After the alignment of the second mask 452, the second mask 452 may be attached to the mask carrier 410, particularly switching the EPMs in a holding state. According to some embodiments, which can be combined with other embodiments described herein, the EPM may be provided with power supplied at the mask frame loading station or the mask handling module 20, respectively. Thereafter, the mask carrier can be moved through the processing system without additional power supply due to utilization of EPMs.

[0062] After loading the second mask on the mask carrier, the orientation of the mask carrier support may be changed from the essentially horizontal orientation depicted in FIG. 4G to the non-horizontal orientation for transport of the mask in the processing system and/or for evaporation of material on a substrate utilizing the mask. The mask carrier 410 carrying the second mask 452 may be transported in the vacuum system in the non-horizontal orientation, e.g. toward a deposition chamber.

[0063] The change of orientation is shown in FIGS. 5A to 5D. As is schematically depicted in FIG. 5A, a method of mask handling according to embodiments described herein includes loading a second mask 452 on the mask carrier 410 (as described above) that is arranged in an essentially horizontal orientation (H) in the vacuum system. The mask carrier 410 may be supported on a mask carrier support 422 that is provided in an essentially horizontal orientation.

[0064] The loading of the second mask 452 on the mask carrier 410 includes attaching the second mask 452, and particularly the mask frame, to the mask carrier 410, e.g. with a magnetic holding arrangement according to embodiments described herein. FIG. 5B schematically shows the second mask 452 being loaded on, and attached to the mask carrier 410 which is horizontally supported on support sections 421 of the mask carrier support 422.

[0065] Methods according to some embodiments described herein further includes changing the orientation of the mask carrier 410 carrying the mask from the essentially horizontal orientation (H) to a non-horizontal orientation (V), particularly to an essentially vertical orientation, as is schematically depicted in FIG. 5C. For example, the mask carrier support 422 with the mask carrier 410 supported thereon may be rotated by an angle of 45° or more and 135° or less, particularly about 90°, until the mask carrier 410 is arranged in the essentially vertical orientation depicted in FIG. 5C. In particular, the orientation change of the mask carrier may include a rotation by an angle of 80° or more and 90° or less. In particular, an actuator such as a motor may be provided for changing the orientation of the mask carrier support 422. As is schematically depicted in FIG. 5C, the mask carrier 410 is moved by an angle together with the mask 452 that is attached thereto. Due to the stiffness of the mask carrier and the magnetic holding arrangement, the flatness of the mask frame in the horizontal orientation can be maintained during change of orientation.

[0066] Methods according to some embodiments described herein further includes transporting the mask carrier 410 carrying the second mask 452 in the non-horizontal orientation (V) along a transport path (T) in the vacuum system. The transport path (T) may extend perpendicular to the paper plane of FIG. 5D. For example, the second mask 452 may be carried by the mask carrier into a deposition chamber where the second mask

452 may be used for depositing an evaporated material on substrates through the second mask.

[0067] The mask carrier 410 may be contactlessly transported in the vacuum system by a mask transport system 550, particularly by a magnetic levitation system. The magnetic levitation system may include a plurality of actively controllable magnetic bearings configured to contactlessly hold the mask carrier 410 at a transport track 551. One or more distance sensors may measure a gap width between the transport track 551 and the mask carrier 410, and a magnetic levitation force of one or more actively controllable magnetic bearings may be controlled depending on the measured distance, in order to maintain the mask carrier at an essentially constant distance with respect to the transport track 551.

[0068] As described above, a mask frame distortion, bending or bulging, i.e. a deviation of the mask frame from a plane can be reduced or prevented by integration of the mask frame with a magnetic holding arrangement at the mask carrier. Further, upon changing the orientation of the mask carrier and, thus, the mask frame to a vertical orientation, gravity acts on the mask carrier and the mask irrespective of distortions. During transferring the mask carrier, the mask carrier top beam, i.e. an upper bar of the mask carrier, can be uniformly lifted. FIG. 1 schematically illustrates a portion of the magnetic levitation system. A plurality of magnetic bearings can be provided to provide the mask carrier 100 in a levitating state. By controlled actuation of the magnetic bearings, and particularly different actuation of the magnetic bearings attracting the mask carrier, uniformity of the mask carrier top beam can be provided. For example, a first magnetic bearing acting at a center of the mask carrier top beam can provide a larger force as compared to magnetic bearings acting at the edges of the top beam of the mask carrier.

[0069] According to yet further embodiments, which can be combined with other embodiments described herein, gravity acting on the mask carrier may also be compensated during substrate processing, i.e. during deposition of material on a substrate while utilizing a mask. In a processing chamber, the mask carrier transported, for example, with a magnetic levitation system can be transferred to a mechanical support system. The mechanical support system can support the mask carrier in the vacuum deposition chamber. Further, the mechanical support system may additionally support the substrate carrier.

[0070] As shown in FIG. 1, the carrier 100 includes carrier clamp engaging elements 120 and carrier clamping engaging elements 122. According to some embodiments, which can be combined with other embodiments described herein, six or more carrier clamp engaging elements can be provided. The carrier clamp engaging elements can be a clamp pin, a magnetic plate, or another structure allowing a clamp system to interact with the carrier. A clamp system is for example described with respect to embodiments illustrated by FIG. 6A.

[0071] As exemplarily shown in FIG. 1, a carrier according to some embodiments of the present disclosure may include one or more first carrier clamp engaging elements 120 and one or more second carrier clamp engaging elements 122. The first carrier clamp engaging elements 120 correspond to first carrier clamps and the second carrier clamp engaging elements correspond to second carrier clamp of a carrier clamp system. For example, four first carrier clamp engaging elements 120 can be provided. As shown in FIG. 1, the fourth carrier clamp engaging elements 120 can be adjacent to corners of the carrier 100. The upper carrier clamp engaging elements may provide a fixed position of the carrier relative to a carrier clamp system in a vertical direction. The upper carrier clamp engaging elements or the carrier clamp system may provide compliance of the respective supports in a horizontal direction. The lower carrier clamp engaging elements 120 may provide compliance of the support in a vertical and a horizontal direction. One of the second carrier clamp engaging elements 122, for example, a carrier clamp engaging element 122 at the top beam of the carrier can provide a fixed position of the carrier relative to the carrier clamp system. For example, the upper second carrier clamp engaging element 122 can provide a positioning reference point. A fine adjustment of the carrier position in the deposition chamber can be provided.

[0072] According to some embodiments, which can be combined with other embodiments described herein, one of the second carrier clamp engaging elements can be configured for a dynamic adjustment. A carrier clamp system can provide a vertical (essentially vertical) force to the carrier at, for example, the lower carrier clamp engaging element 122 shown in FIG. 1. Gravity acting on the carrier can be actively compensated for by the force applied to the carrier with the clamp system.

[0073] According to some embodiments, which can be combined with other embodiments described herein, one or more first carrier clamp engaging elements 120 can

provide the support of the carrier with a mechanical support system, for example, a carrier clamp system. For example, four first carrier clamp engaging elements can be provided. According to some embodiments, which can be combined with other embodiments described herein, a compliance of the support in one or two directions parallel to the plane of the substrate carrier can avoid a mechanical over definition of the position that may eventually introduce distorting forces. One or more of the first carrier clamp engaging elements can provide a first compliance in the plane of the carrier. One or more of the first carrier clamp engaging elements can provide a second compliance in the plane of the carrier being different to the first compliance.

[0074] Additionally or alternatively, one or more of the second carrier clamp engaging elements 122, for example carrier clamp engaging elements provided adjacent to a center of the carrier, can provide a reference position. The reference position allows for adjustment of the carrier position in a vacuum deposition chamber. Yet further additionally or alternatively, one or more of the second carrier clamp engaging elements 122 provided adjacent to a center of the carrier can be configured for dynamic adjustment of the pixel positioning accuracy, for example by deformation of the carrier. The deformation of the carrier by forces from e.g. a carrier clamp system may counteract the gravity acting on the carrier.

[0075] According to some embodiments, which can be combined with other embodiments described herein, carrier clamping, carrier clamps of a carrier clamp system in a vacuum deposition chamber, and/or carrier clamp engaging elements on a carrier can be provided at six or more positions. The six or more positions can be at least four outer positions and two inner positions, which are horizontally between the outer positions.

[0076] Additional or alternative modifications of embodiments of the present disclosure are described with respect to FIG. 6A. In the following. FIG. 6A shows a carrier 100 for carrying a mask 150 and a carrier 270 for carrying a substrate 250. A carrier clamp system 600 configured to support exemplarily the carrier 100 is further shown in FIG. 6A. The carrier clamp system 600 can, for example, be provided or coupled to wall 650 of a vacuum chamber of a deposition chamber. The carrier clamp system 600 includes carrier clamp 602. The carrier clamps 602 can interact or engage with carrier clamp engaging elements 520 of the carrier 100. For example, a carrier clamp pin 522 can be provided at

the clamp engaging element 520. The carrier clamp system 600 shown in FIG. 6A is configured to clamp the carrier 100 for supporting the mask 150. Additionally, the carrier clamp system can include carrier clamps (not shown) to engage or interact with carrier clamp engaging elements of a substrate carrier 270.

[0077] The carrier 100 shown in FIG. 6A includes the carrier body 110 having an opening 112. Further, one or more magnetic holders 130 are coupled to the carrier body 110. The carrier 100 includes a mechanical coupling 524. The mechanical coupling 524 couples the magnetic holder 130 to the carrier clamp engaging element 520. As indicated by the arrows in FIG. 6A, upon movement of the carrier clamp 602, a magnetic holder 130 can be moved. According to some embodiments, which can be combined with other embodiments described herein, a magnetic holder of the magnetic holding arrangement can be movable, particularly in a vertical direction, relative to the carrier body 110. A carrier clamp engaging element 520 as shown in FIG. 6A allows for application of force to the mask frame 152 attached to a magnetic holder 130. For example, a magnetic holder provided adjacent to or at the center of the carrier 100 can be moved to compensate for gravity deformation. A movement of the magnetic holder may act upon the mask frame connected to the magnetic holder.

[0078] According to some embodiments, which can be combined with other embodiments described herein, at least one carrier clamp engaging element of the carrier clamp engaging elements of the carrier 100 is coupled to at least one magnetic holder of the magnetic holding arrangement to move the magnetic holder parallel to a surface of the carrier body. The magnetic holder coupled to the carrier clamp engaging element is movable by moving the carrier clamp engaging element and/or a carrier clamp 602 of a carrier clamp system 600.

[0079] FIG. 6B shows a further exemplary illustration of a carrier 100. Embodiments of the present disclosure are described with respect to FIG. 6B in the following. The carrier 100 includes a carrier body 110 having an opening. A plurality of magnetic holders 130 is arranged around the opening in the carrier body. Further, clamp engaging elements 520 can be provided, as described herein.

[0080] According to some embodiments, which can be combined with other embodiments described herein, one or more, for example, two or more clamp engaging elements 520 are provided on a first side of the opening in the carrier body. For example, the first side can be an upper side in an operation orientation of the carrier 100. Further, one or more, for example, two or more clamp engaging elements 520 are provided on a second side of the opening opposing the first side. For example, the second side can be lower side in an operation orientation of the carrier 100.

[0081] According to some embodiments, which can be combined with other embodiments described herein, three upper carrier engaging elements 520 are provided and three lower carrier engaging elements are provided. One of the upper carrier engaging elements is provided between the other two upper carrier engaging elements. One of the lower carrier engaging elements is provided between the other two lower carrier engaging elements. For example, a first upper carrier engaging element can be at or adjacent to a center and/or a first lower carrier engaging element can be at or adjacent to a center. The first upper carrier engaging element can be coupled with a mechanical coupling, for example, a bar, to magnetic holder 130. Yet further, additionally or alternatively the first lower carrier engaging element can be coupled with mechanical coupling 524, for example, a bar, to a magnetic holder 130.

[0082] As illustrated in FIG. 6B, the mask frame 152 can be attached to the carrier 100 with the magnetic holders 130. The magnetic holders 130, which can according to embodiments of the present disclosure include an electro permanent magnet, can be coupled to or integrated with the carrier body 110. According to some embodiments, which can be combined with other embodiments described herein, a compliance of the integration of the magnetic holders on the carrier can provide compliance to maintain micron level accuracy, in spite of thermal expansion and/or other distortions, i.e. other distortion impact.

[0083] As shown in the enlarged portions in FIG. 6B, according to some embodiments, which can be combined with other embodiments described herein, a magnetic holder 130 can be supported at the carrier body 110 with a linear guiding element 642. For example, bearing 643 can be provided between the magnetic holder 130 and the linear guiding element 642. The support with a linear guiding element 642 allows for a translation of the magnetic holder 130 relative to the carrier body 110 in at least one direction as indicated

by arrow 632. Additionally, a second linear guiding element 644 and a second bearing 645 can be provided. The support with a second linear guiding element 644 allows for a further translation of the magnetic holder 130 relative to the carrier body 110 in at least a second direction as indicated by arrow 633.

[0084] According to yet further embodiments, which can be combined with other embodiments described herein, the compliance of a magnetic holder 130 relative to the carrier body 110 can be provided by a hinge element, wherein structures are formed in a plate allowing for a movement of the magnetic holder in a first direction and fixing the magnetic holder in a second direction different than the first direction, for example, perpendicular to the first direction. A hinge element may further allow for a movement of the magnetic holder relative to the carrier body into directions, for example, to perpendicular directions. The magnetic holder can be fixed relative to the carrier body in a third direction perpendicular to the first direction and/or the second direction.

[0085] FIG. 6B shows the X-direction and the Y-direction. During transfer of a carrier in a vertical substrate processing system or during processing of the substrate in a vertical substrate processing system, the X-direction of a carrier may correspond to a horizontal direction. The Y-direction of a carrier corresponds to a vertical, i.e. essentially vertical direction. According to some embodiments, which can be combined with other embodiments described herein, at least two upper magnet holders 130 are provided. The first upper magnet holder 130 can be coupled to the carrier body 110 to be movable along the X-direction and fixed in the Y-direction. The second upper magnet holder can be coupled to the carrier body 110 to be movable along the Y-direction. Yet further, the second upper magnet holder may also be fixed in the X-direction. According to some embodiments, which can be combined with other embodiments described herein, a third upper magnet holder can be coupled to the carrier body 110 similar as the first upper magnet holder. The second upper magnet holder can be provided between the first upper magnet holder and the third upper magnet holder.

[0086] According to some embodiments, which can be combined with other embodiments described herein, the second upper magnet holder can be movable as indicated by arrow 631 may be mechanically coupled to a clamp engaging element 520, for

example, by mechanical coupling 524. Accordingly, as described above, movement of the clamp engaging element results in movement of the magnetic holder 130.

[0087] According to some embodiments, which can be combined with other embodiments described herein, at least two lower magnet holders 130 are provided. The first lower magnet holder 130 can be coupled to the carrier body 110 to be movable along the X-direction and movable in the Y-direction. The second lower magnet holder can be coupled to the carrier body 110 to be movable along the Y-direction. Yet further, the second lower magnet holder may be fixed in the X-direction. According to some embodiments, which can be combined with other embodiments described herein, a third lower magnet holder can be coupled to the carrier body 110 similar as the first upper magnet holder. The second lower magnet holder can be provided between the first lower magnet holder and the third lower magnet holder. According to some embodiments, which can be combined with other embodiments described herein, the second lower magnet holder can be movable as indicated by arrow 631 may be mechanically coupled to a clamp engaging element 520, for example, by mechanical coupling 524. Accordingly, as described above, movement of the clamp engaging element results in movement of the magnetic holder 130.

[0088] According to yet further embodiments, which can be combined with other embodiments described herein, one or more magnetic holders can be provided at a side of the mask frame or the opening in the carrier body 110, respectively. One or more magnetic holders can be provided at each side of the opening or the mask frame, respectively. According to some embodiments, which can be combined with other embodiments described herein, a side magnetic holder can be movable -direction and movable in the Y-direction.

[0089] The above-described embodiments referred to a connection between one or more magnetic holders and the carrier body to have a compliance or to be movable in one or more directions. Accordingly, a movement of the carrier frame, for example, due to thermal expansion, in the one or more directions is free. A movement in other directions, for example, in Z-direction can be fixed.

[0090] As described above, a top beam deformation of the top beam of the carrier can be compensated by magnetic bearings of a magnetic levitation system, a carrier deformation can be compensated by a force acting on a carrier clamp engaging element of the carrier, or a deformation can be compensated by a force acting on the mask frame, particularly by movement of a magnetic holder. The movement of the magnetic holder can be provided by movement of a carrier clamp engaging element and mechanical coupling between the carrier clamp engaging element and the magnetic holder. These compensation mechanisms can be provided individually or in combination with each other.

[0091] FIG. 6A further shows the substrate chucked to an electrostatic chuck 272 of a substrate carrier 270. In a processing chamber the substrate supported by the substrate carrier is transferred behind the mask, i.e. the mask is provided between the deposition source, such as an evaporation source for organic material, and the substrate supported by the substrate carrier.

[0092] An alignment of the substrate and the mask can be provided. For example, a camera 690 or another vision system can be provided in a vacuum deposition chamber. An optical mask alignment module may provide feedback to actuators of a clamping system for alignment. An alignment of the mask and the substrate parallel to a plane of the substrate or the mask, respectively, can be provided by the carrier clamp system having actuation alignment actuators. Further, the carrier clamp system may allow for alignment perpendicular to the plane of the substrate or the mask, respectively. Particularly, the substrate and the mask can be aligned to be parallel. Due to the flatness of the mask integrated by the magnetic holding arrangement at the mask carrier the parallel alignment is improved. The substrate can be brought in close vicinity to the mask sheet. Thereafter, the mask sheet is chucked by magnet 274 to the substrate for pattern generation with the deposition material. According to some embodiments, an alignment of the mask and the substrate can be provided relative to each other, i.e. the mask and/or the substrate can be moved by alignment actuators of, for example, a clamping system. Considering the challenges of providing pixel positioning accuracy in a vertical orientation, particularly for large area substrates, an alignment system may move the substrate or the substrate carrier, respectively, relative to the mask. Forces applied by an alignment system clamping system

to the mask carrier may allow for fine adjustment or compensation of deformation of the carrier for the mask.

[0093] A carrier clamp system having alignment actuators or a corresponding alignment system including carrier clamps may allow for dynamic adjustment in an X-Y-plane, i.e. a plane of the mask sheet or the substrate receiving surface of a substrate carrier, and in a Z-direction, i.e. perpendicular to the plane of the mask sheet or the substrate receiving surface of a substrate carrier. A feedback control can be provided by a vision system, for example camera 690 shown in FIG. 6A. Mask carrier deformation by gravity can be compensated by applying forces to one or more carrier clamp engaging elements of the carrier.

[0094] FIG. 9 illustrates a method of aligning a mask relative to a substrate in a processing chamber. At operation 910, the mask is supported with a mask carrier by a magnetic holding arrangement having one or more magnetic holders arranged at a carrier body of the mask carrier around an opening of the carrier body. At operation 920, the substrate is supported with a substrate carrier. At operation 930, the mask carrier is supported with a mechanical support, e.g. a mask carrier clamp system having one or more first mask carrier clamps and one or more second mask carrier clamps. At operation 940, the one or more second mask carrier clamps are moved relative to the one or more first carrier clamps to deform the mask frame or the mask carrier. Accordingly, carrier deformation by gravity can be compensated for. Further optional operations may include optically inspecting one or more mask position marks relative to one or more substrate position marks.

[0095] FIG. 7 shows a vacuum processing system 700, according to an embodiment of the present disclosure. The vacuum processing system includes a plurality of deposition chambers 701, wherein each deposition chamber houses a deposition source, such as an evaporation source 705. The present disclosure is however not restricted to vacuum systems with evaporation sources. For example, a chemical vapor deposition (CVD) system, or another physical evaporation deposition (PVD) system, e.g. a sputter system, may be provided.

[0096] An evaporation source 705 includes an evaporation crucible configured to evaporate a material, and a distribution pipe with a plurality of openings for directing the

evaporated material toward a substrate which is arranged in a deposition area of a deposition chamber. The distribution pipe may extend in an essentially vertical direction. In some embodiments, the distribution pipe may be rotatably mounted. For example, the distribution pipe may be rotatable between a first deposition area of a deposition chamber and a second deposition area of the deposition chamber, wherein the first deposition area and the second deposition area may be arranged on opposite sides of the evaporation source 705. Accordingly, after the deposition of an evaporated material on a first substrate arranged in the first deposition area, the distribution pipe may be rotated by an angle of about 180° for depositing the evaporated material on a second substrate arranged in the second deposition area of the deposition chamber. In FIG. 7, two substrates 715 are exemplarily depicted in the two deposition areas of the deposition chamber 702 on opposite sides of the evaporation source 705. The remaining substrates are not depicted in FIG. 7 for the sake of simplicity.

[0097] The vacuum processing system 700 may be a vacuum deposition system configured to coat substrates, e.g. thin glass substrates, with a layer stack, e.g. for display applications. The substrates may be attached to substrate carriers in the vacuum system, and the substrate carriers may be transported through the vacuum system by a substrate transport system. The substrate carriers may be transported by the substrate transport system into a plurality of deposition chambers in succession, in order to deposit a stack of different materials on the substrates. The main surfaces of the substrates may be coated with thin coating layers in the deposition chambers, while the substrates are positioned in front of an evaporation source which moves past the substrate at a predetermined speed. Alternatively, the substrates may be transported past the coating devices at a predetermined speed during the deposition.

[0098] The substrates may be inflexible substrates, e.g. wafers, slices of transparent crystal such as sapphire or the like, glass substrates, or ceramic plates. However, the present disclosure is not limited thereto and the term substrate may also embrace flexible substrates such as a web or a foil, e.g. a metal foil or a plastic foil.

[0099] The substrates may be large area substrates in some embodiments. A large area substrate may have a surface area of 1 m^2 or more. Specifically, a large area substrate may be used for display manufacturing and be a glass or plastic substrate. For example,

substrates as described herein shall embrace substrates which are typically used for an LCD (Liquid Crystal Display), a PDP (Plasma Display Panel), and the like. In some embodiments, a large area substrate can be GEN 4.5, which corresponds to about 0.67 m^2 substrates (0.73 x 0.92m), GEN 5, which corresponds to about 1.4 m^2 substrates (1.1 m x 1.3 m), or larger. A large area substrate can further be GEN 7.5, which corresponds to about 4.29 m^2 substrates (1.95 m x 2.2 m), GEN 8.5, which corresponds to about 5.7m^2 substrates (2.2 m x 2.5 m), or even GEN 10, which corresponds to about 8.7 m^2 substrates (2.85 m × 3.05 m). Even larger generations such as GEN 11 and GEN 12 and corresponding substrate areas can similarly be implemented. Half sizes of the GEN generations may also be provided in OLED display manufacturing. In some implementations, an array of smaller sized substrates with surface areas down to a few cm^2, e.g. 2 cm x 4 cm and/or various individual shapes may be positioned on a single substrate support. The masks may be larger than the substrates in some embodiments in order to provide for a complete overlap with the substrates during deposition. In some implementations, a thickness of the substrate in a direction perpendicular to the main surface of the substrate may be 1 mm or less, e.g. from 0.1 mm to 1 mm.

[00100] The vacuum processing system 700 further includes a mask handling module 20 configured to connect and separate masks and mask carriers under vacuum. The mask handling module 20 is further configured to change an orientation of the masks between an essentially horizontal orientation (H) and a non-horizontal orientation (V), particularly an essentially vertical orientation. In some embodiments, the mask handling module 20 is configured to change the orientation of the mask carriers together with the respective mask attached thereto, as described herein.

[00101] According to an embodiment of the present disclosure, a mask handling module includes a power supply for switching electro permanent magnets of a magnetic holding arrangement of a carrier from a supporting state to non-supporting state.

[00102] According to an embodiment, a mask handling module may include a vacuum chamber, a support table or mask carrier support 422 in the vacuum chamber for supporting a mask carrier, the support table being movable by an angle between a non-vertical orientation, particularly a horizontal orientation, and a non-horizontal orientation, particularly an essentially vertical orientation. The mask handling module further includes

an assembly of lift pins configured to support a mask having a mask frame and a mask sheet over the support table, a camera configured to detect a position of the mask distant over the mask carrier and relative to the carrier and one or more alignment actuators aligning the position of the mask relative to the mask carrier.

[00103] The vacuum processing system 700 further includes a mask transport system configured to transport the mask carriers carrying the masks in the non-horizontal orientation between the mask handling module 20 and the plurality of deposition chambers 701. For example, masks to be used may be fixed to a respective mask carrier by the mask handling module 20 with a magnetic holding arrangement and may be transported to a respective deposition chamber by the transport system.

[00104] The mask handling module 20 may be configured to change the orientation of a mask, particularly together with the mask carrier carrying the mask, between an essentially horizontal orientation and a non-horizontal orientation.

[00105] In particular, the mask handling module 20 may include a mask carrier support 422 configured to support a mask carrier 410 and to change the orientation of the mask carrier between the essentially horizontal orientation and the essentially vertical orientation. For example, an actuator may be provided for changing the orientation of the mask carrier support 422 between the non-horizontal orientation (V) and the essentially horizontal orientation (H).

[00106] In some embodiments, the mask handling module 20 may further include a vacuum robot 730. The vacuum robot may be configured to unload a mask from a mask carrier that is supported by the mask carrier support. The vacuum robot may be further configured to load a mask on a mask carrier that is supported by the mask carrier support.

[00107] The vacuum robot 730 may be provided next to the mask carrier support 422 in a vacuum chamber of the vacuum system, and one, two or more load lock chambers 708 may be arranged next to the vacuum chamber. Mask holders, e.g. mask shelves 709, may be provided in or at the load lock chambers 708. The vacuum robot 730 may be configured to transfer masks between the one, two or more load lock chambers 708 and the mask carrier support 422.

[00108] As is schematically depicted in FIG. 7, the vacuum system may include one single mask handling module 20 for handling the masks that are to be distributed into the plurality of deposition chambers 701, particularly four, six, eight, ten or more deposition chambers.

[00109] In some embodiments, which may be combined with other embodiments described herein, the vacuum system includes a main transportation path with transportation tracks for transporting mask carriers and substrate carriers along the main transportation path, the mask handling module 20 being connected to a first section of the main transportation path, a substrate handling module 715 configured to connect and separate substrates and substrate carriers being connected to a second section of the main transportation path, and the plurality of deposition chambers 701 being connected to a third section of the main transportation path. The main transportation path may extend in an essentially linear direction, the first section may be a first end section of the main transportation path, and the second section may be a second end section of the main transportation path. The third section may be partially or entirely provided between the first section and the second section.

[00110] 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. A carrier for a mask, comprising:

a carrier body having a surface configured to face at least a portion of the mask, the carrier body having an opening for material deposition; and

a magnetic holding arrangement having one or more magnetic holders arranged at the carrier body around the opening of the carrier body.

2. The carrier according to claim 1, further comprising

six or more carrier clamp engaging elements for interacting with clamps of a carrier clamp system.

3. The carrier according to claim 2, wherein at least one carrier clamp engaging element of the six or more carrier clamp engaging elements is coupled to a first magnetic holder of the one or more magnetic holders to move the first magnetic holder parallel to the surface of the carrier body, particularly wherein the first magnetic holder is movable by moving the at least one carrier clamp engaging element.

4. The carrier according to any of claims 1 to 3, wherein the one or more magnetic holders include an electro permanent magnet.

5. The carrier according to any of claims 1 to 4, wherein the carrier body includes one or more recesses and the one or more magnetic holders are provided in the one or more recesses.

6. The carrier according to any of claims 1 to 5, further comprising:

one or more height adjustment elements to adjust the one or more magnetic holders in height relative to the surface of the carrier body.

7. The carrier according to any of claims 1 to 6, wherein the one or more magnetic holders have a mask contacting surface protruding from the surface to form a gap between a mask frame of the mask and the surface of the carrier body, particularly wherein the gap is 0.8 mm or below.

8. The carrier according to any of claims 1 to 7, wherein the magnetic holding arrangement provides at least one of: the magnetic holding arrangement extends along at least 10% of the perimeter of the opening, at least 8 magnetic holders are provided, at least 5 magnetic holders are provided and are distributed around the perimeter of the opening.

9. The carrier according to any of claims 1 to 8, wherein one or more supports for the one or more magnetic holders are provided, the one or more supports coupling the one or more magnetic holders to the carrier body; the one or more supports comprise:

at least one support allowing a movement of at least one magnetic holder in a horizontal direction and fixing the at least one magnetic holder in a vertical direction;

at least one support allowing fixing at least one magnetic holder in a horizontal direction and fixing the at least one magnetic holder in a vertical direction; and/or

at least one support allowing a movement of at least one magnetic holder in a vertical direction and fixing the at least one magnetic holder in a horizontal direction.

10. A mask handling module, comprising:

a vacuum chamber; and

a power supply configured to provide power to a mask carrier for switching of one or more EPMs within the vacuum chamber.

11. The mask handling module of claim 10, further comprising:

a support table in the vacuum chamber for supporting the mask carrier, the support table being movable by an angle between a non-vertical orientation, particularly a horizontal orientation, and a non-horizontal orientation, particularly an essentially vertical orientation;

an assembly of lift pins configured to support a mask having a mask frame and a mask sheet over the support table;

a camera configured to detect a position of the mask distant over the mask carrier and relative to the carrier; and

one or more alignment actuators aligning the position of the mask relative to the mask carrier.

12. A method of loading a mask on a mask carrier; comprising

chucking a mask frame of the mask at a horizontal orientation with a magnetic holding arrangement having the one or more EPMs arranged at the carrier body around an opening of the carrier body.

13. The method of claim 12, further comprising:

aligning the position of the mask relative to the mask carrier before chucking.

14. The method of any of claims 12 to 13, wherein the chucking comprises:

activating a first magnetic holder of the one or more magnetic holders before activating a second holder of the one or more magnetic holders, wherein the first magnetic holder is closer to a mask frame portion center than the second magnetic holder.

15. A method of aligning a mask relative to a substrate in a processing chamber, the method comprising:

supporting the mask with a mask carrier by a magnetic holding arrangement having one or more magnetic holders arranged at a carrier body of the mask carrier around an opening of the carrier body;

supporting the substrate with a substrate carrier;

supporting the mask carrier with a mask carrier clamp system, the mask carrier clamp system having one or more first mask carrier clamps and one or more second mask carrier clamps;

moving the one or more second mask carrier clamps relative to the one or more first carrier clamps to deform the mask frame or the mask carrier.

16. The method of claim 15, further comprising:

optically inspecting one or more mask position marks relative to one or more substrate position marks.

FIG. 1

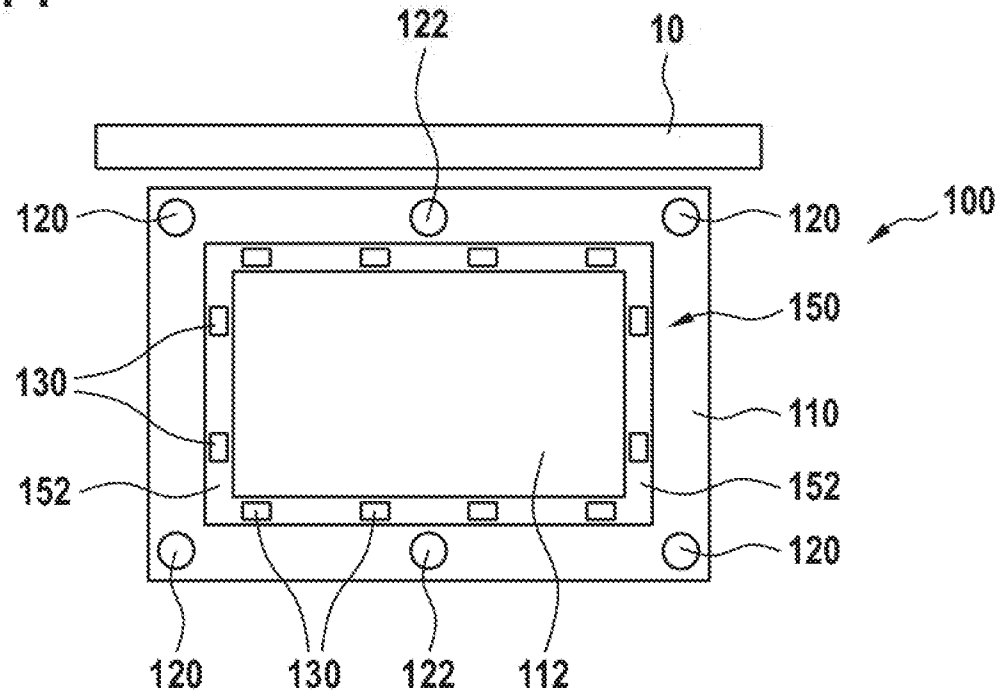

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FIG. 2

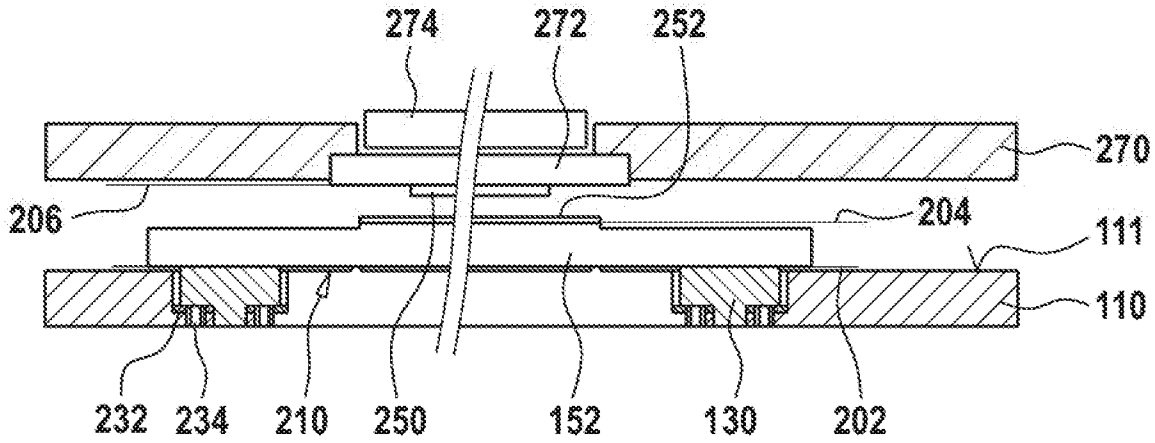

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FIG. 3A

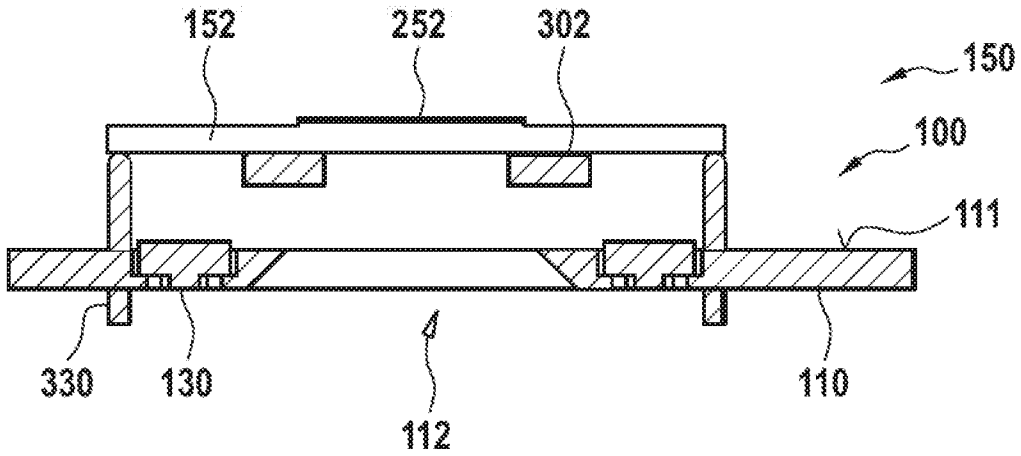


FIG. 3B

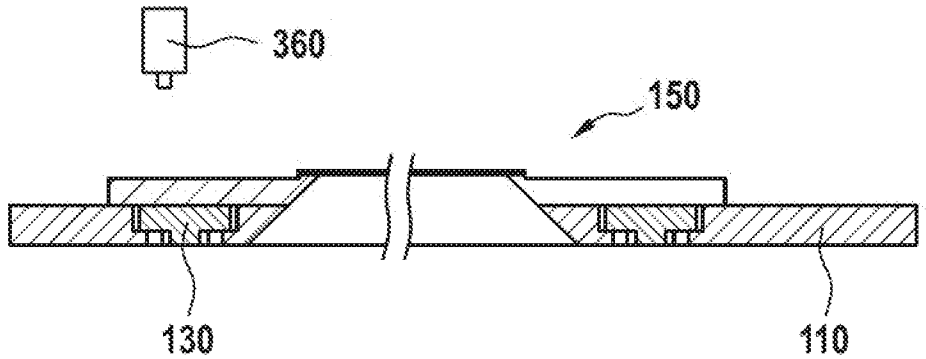


FIG. 4A

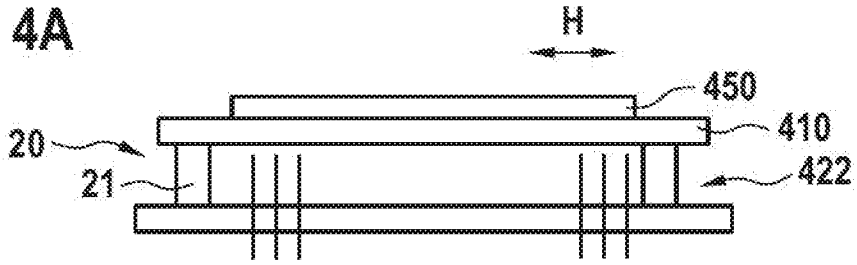


FIG. 4B

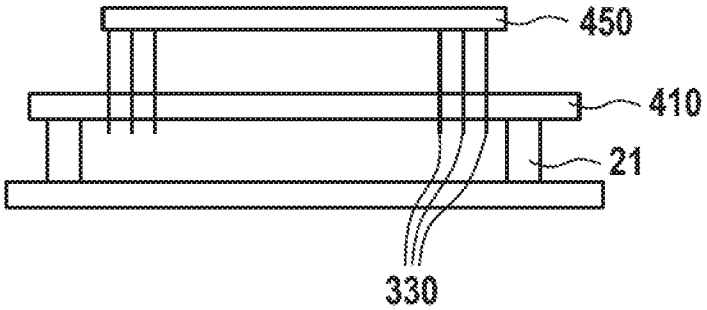


FIG. 4C

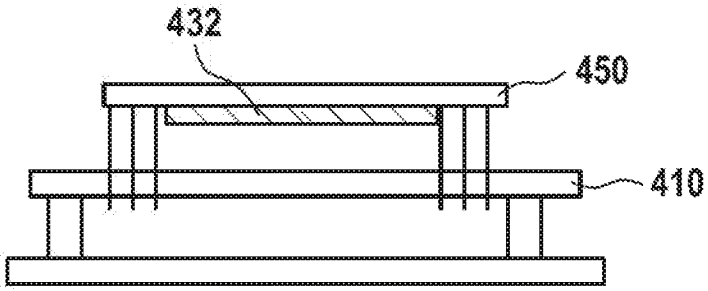


FIG. 4D

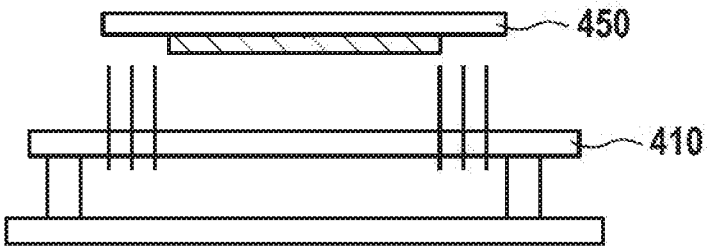


FIG. 4E

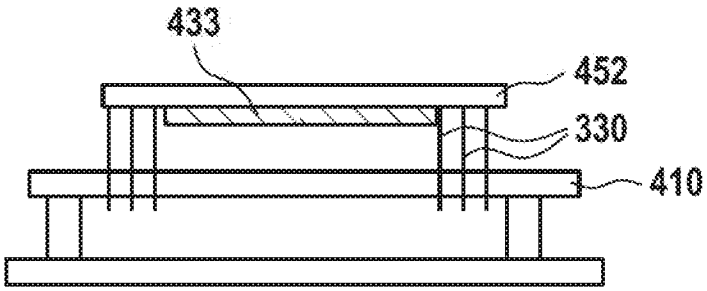


FIG. 4F

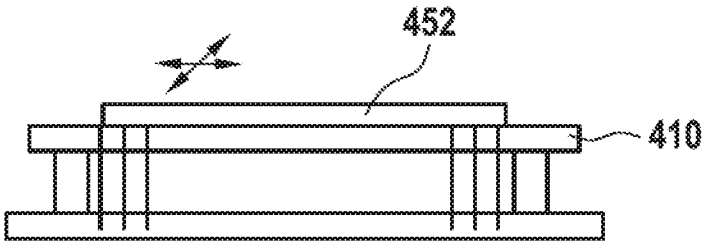


FIG. 4G

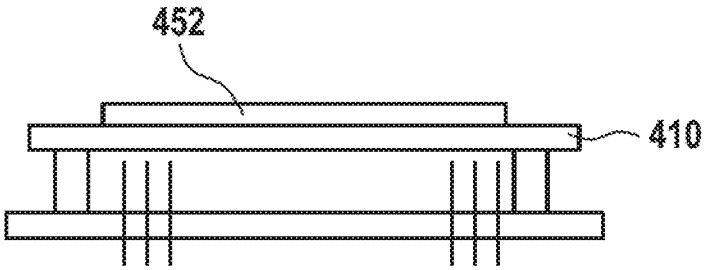


FIG. 5A

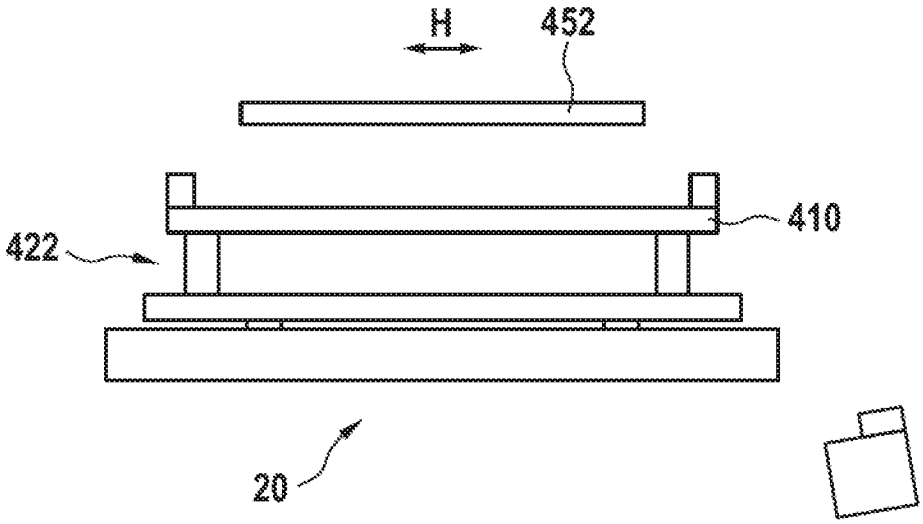


FIG. 5B

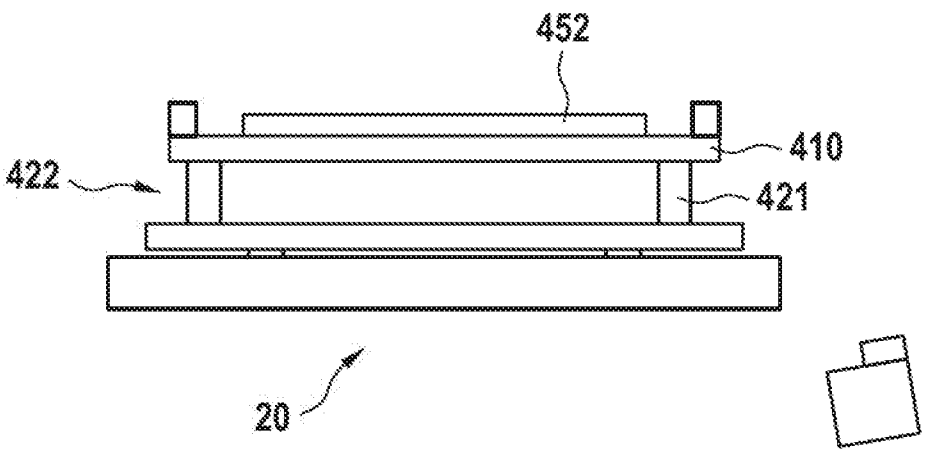


FIG. 5C

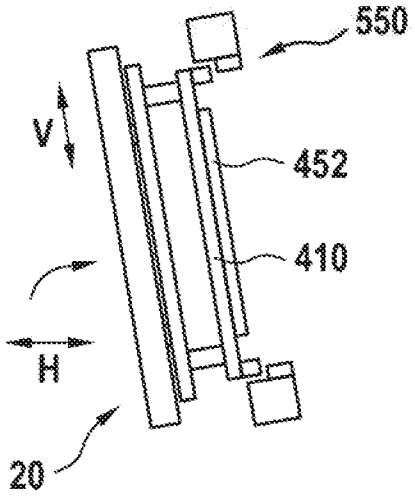


FIG. 5D

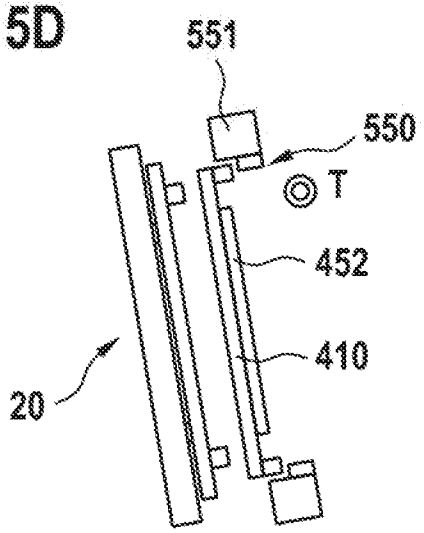
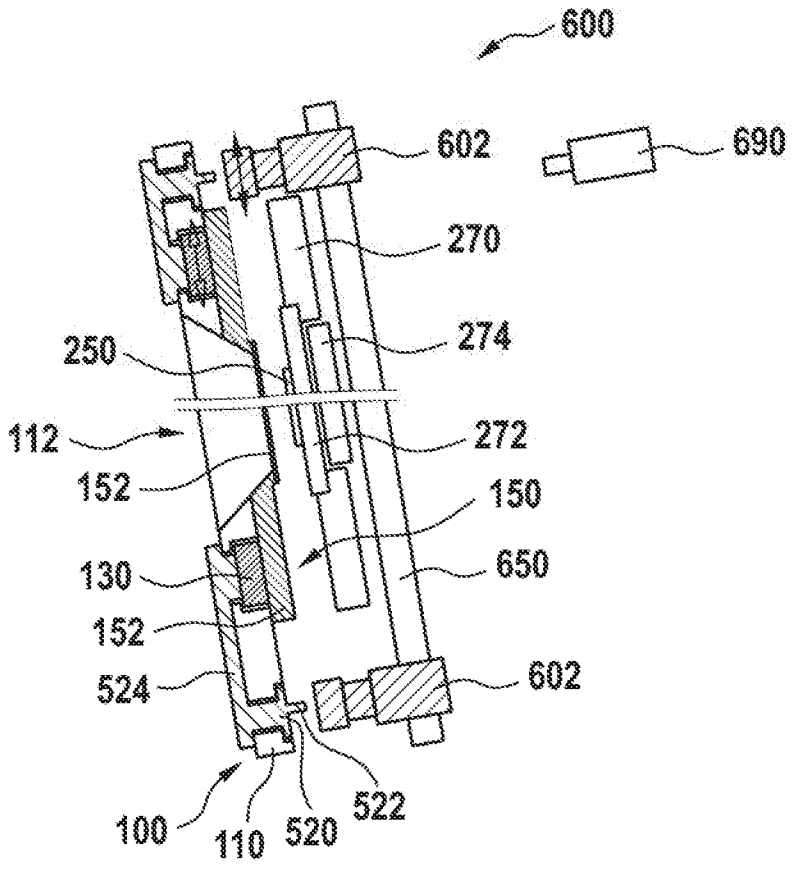


FIG. 6A



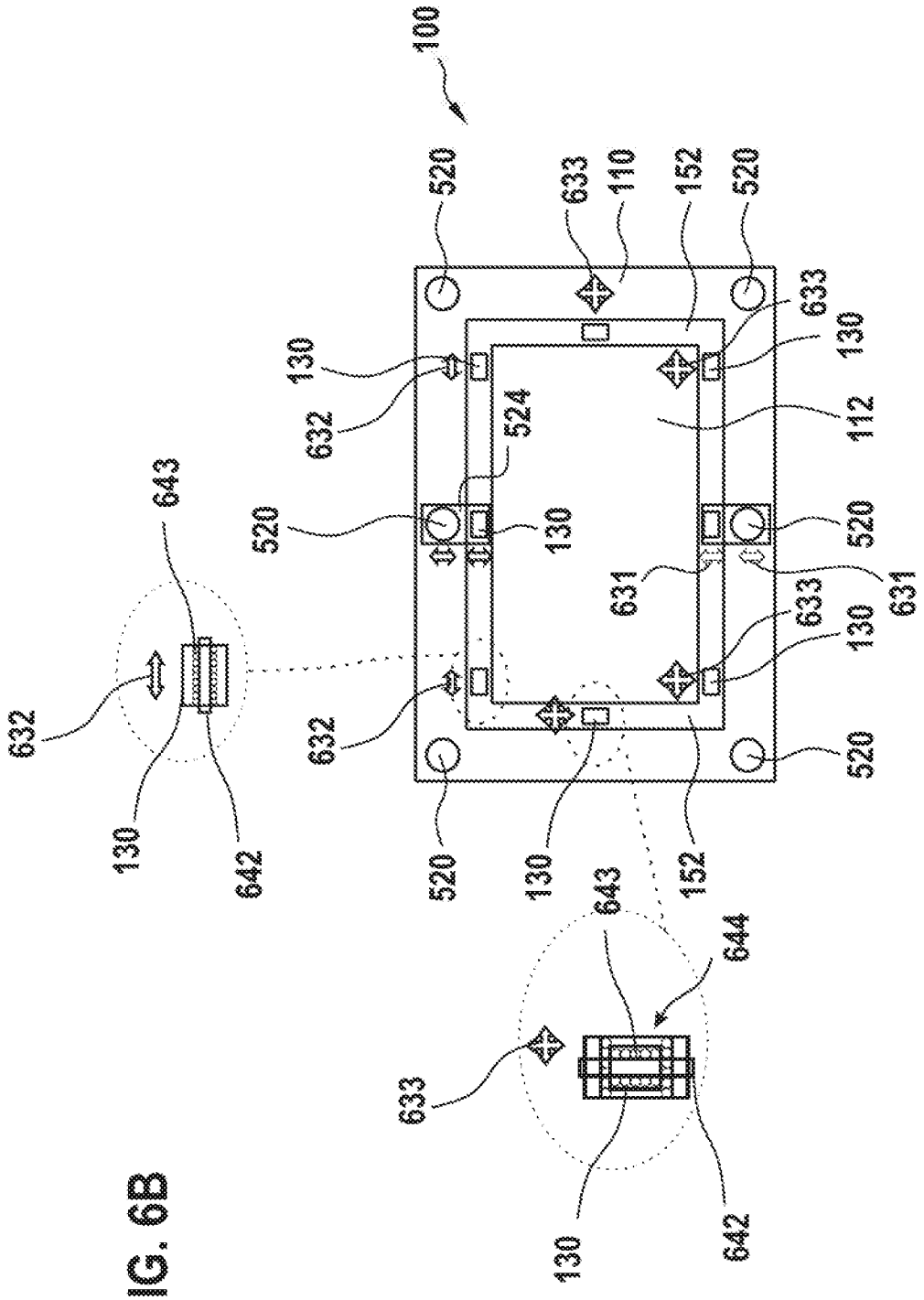

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FIG. 6B

FIG. 7

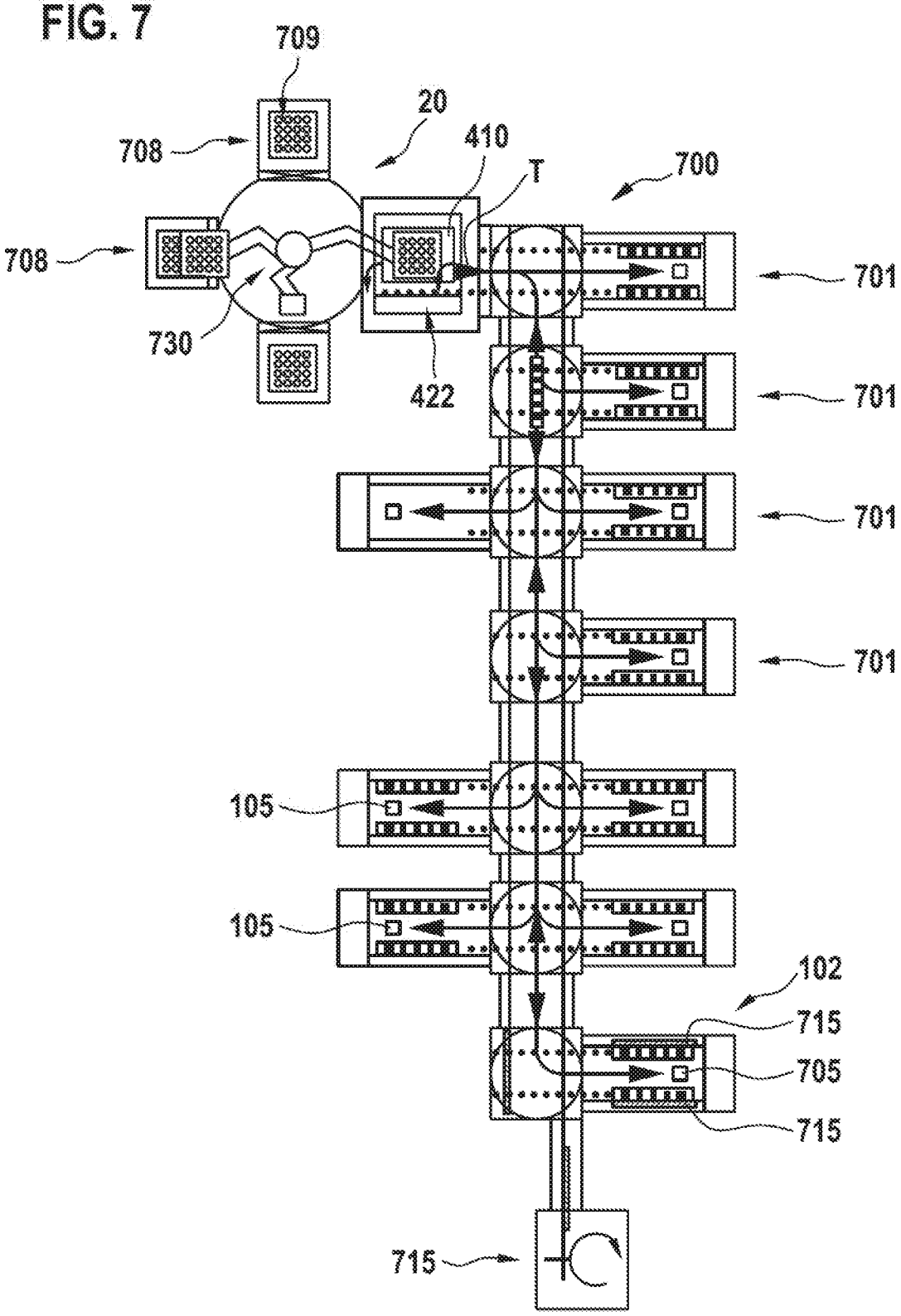

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FIG. 8

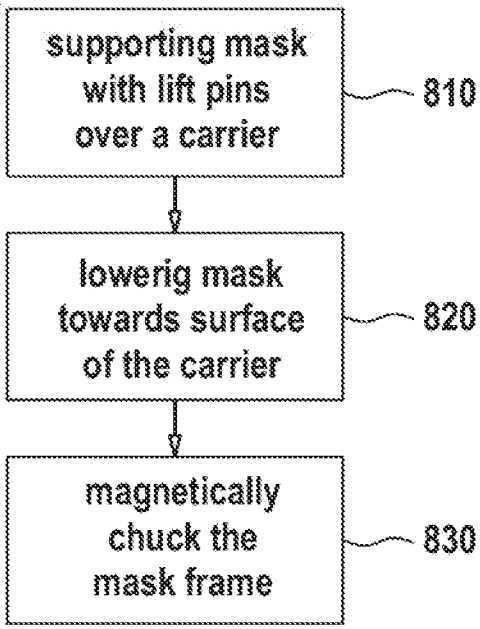
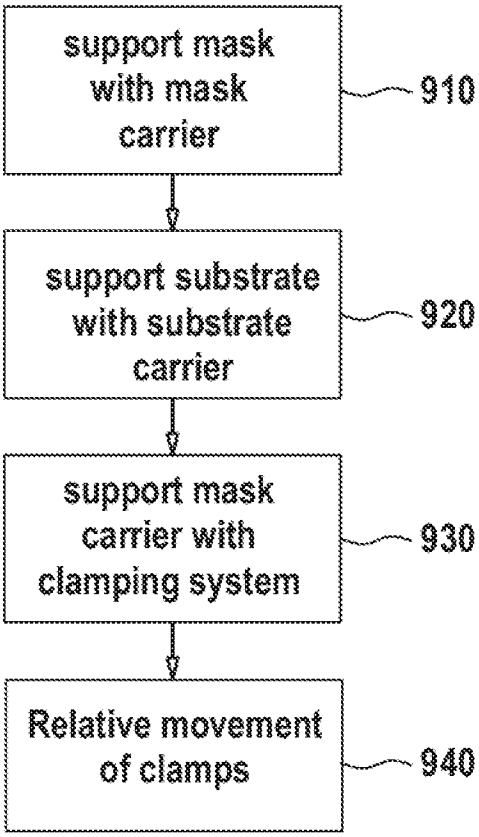

supporting mask with lift pins over a carrier
810
lowerig mask towards surface of the carrier
820
magnetically chuck the mask frame
830

FIG. 9


support mask with mask carrier
910
support substrate with substrate carrier
920
support mask carrier with clamping system
930
Relative movement of clamps
940

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2019/021217

A. CLASSIFICATION OF SUBJECT MATTER

H01L 21/677(2006.01)i, H01L 51/56(2006.01)i, H01L 21/687(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)
H01L 21/677; C23C 14/04; C23C 14/24; C23C 14/34; C23C 14/48; C23C 16/00; C23F 1/00; G01B 11/27; H01L 51/56; H01L 21/687

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: mask, carrier, magnet, electro permanent magnet, clamp, support, table, pin

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2014-0165906 A1 (VARIAN SEMICONDUCTOR EQUIPMENT ASSOCIATES, INC.) 19 June 2014 See paragraphs [0015]-[0034], claim 17, and figures 1C, 4-5.	1,4-8,10,12-14
Y		11
A		2-3,9,15-16
Y	US 2018-0363127 A1 (ADVANTECH GLOBAL, LTD.) 20 December 2018 See paragraphs [0063]-[0066] and figures 1-5.	11
A	WO 2017-129245 A1 (APPLIED MATERIALS, INC. et al.) 03 August 2017 See paragraphs [0033]-[0034] and figures 2A-2B.	1-16
A	JP 2014-088606 A (JVC KENWOOD CORP.) 15 May 2014 See paragraphs [0019]-[0033] and figures 2-6.	1-16
A	US 8361230 B2 (MANZ, DIETE) 29 January 2013 See claims 1-2 and figures 1-4.	1-16

☐ 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
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
06 December 2019 (06.12.2019)	**06 December 2019 (06.12.2019)**

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Telephone No. +82-42-481-3325

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2019/021217

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