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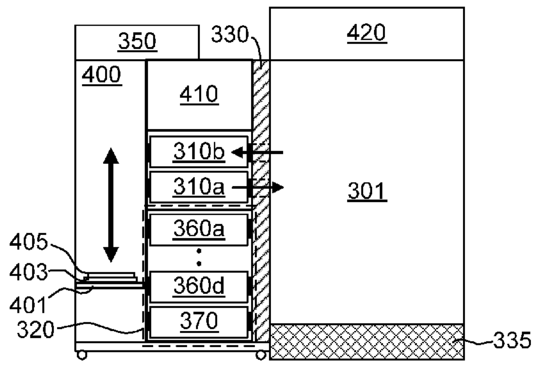
[Continued on next page]

(54) **Title**: METHOD OF PROCESSING A SUBSTRATE IN A LITHOGRAPHY SYSTEM

FIG. 4



(57) **Abstract**: A method of processing substrates in a lithography system unit of a lithography system, the lithography system unit comprising at least two substrate preparation units (360a-360d), a load lock unit (310) comprising at least first and second substrate positions, and a substrate handling robot for transferring substrates between the substrate preparation units and the load lock unit. The method comprises providing a sequence of substrates to be exposed to the robot, including an Nth substrate, an N-1th substrate immediately preceding the Nth substrate, and an N+1th substrate immediately following the Nth substrate; transferring the Nth substrate by means of the robot to a first one of the substrate preparation units; clamping the Nth substrate on a first substrate support structure in the first substrate preparation unit, the Nth substrate and first substrate support structure together forming a clamped Nth substrate; transferring the clamped Nth substrate by means of the robot from the first substrate preparation unit to an unoccupied one of the first and second positions in the load lock unit for exposure in the lithography system unit; and exposing the clamped Nth substrate in the lithography system unit.

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Method of processing a substrate in a lithography system

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a method of processing substrates in a lithography system, and in particular to a method for transferring substrates between substrate preparation units and load lock unit of a lithography system.

2. Description of the Related Art

[0002] In the semiconductor industry, an ever increasing desire to manufacture smaller structures with high accuracy and reliability puts great demands on wafer processing technology. In particular, it is important to maximize wafer throughput of wafer processing equipment while maintaining the lowest capital costs and operational costs, and without excessive use of floor space. Floor space in a semiconductor manufacturing environment is expensive, as most space needs to meet high standard clean room conditions. Therefore, the floor space that is to be occupied by wafer processing equipment, i.e. the so-called footprint, is preferably as limited as possible. Furthermore, to ensure that clean room conditions can be maintained, wafer processing equipment is preferably serviced within the clean room.

[0003] A very critical step in the manufacturing of integrated circuits on a wafer is lithography. In a lithography process, a predetermined pattern is transferred onto a semiconductor substrate, often referred to as a wafer. Currently, the smallest dimensions of structures patterned with a lithography apparatus are about 70 nm in size. However, to produce even more complex circuits, structures of smaller size are desired.

[0004] The throughput of lithography systems is also a critical factor. Charged particle lithography machines are capable of patterning substrates at extremely small dimensions, but at a lower throughput. Currently, optical lithography machines are available which can pattern about 100 wafers per hour. A cluster of 10 charged particle lithography machines, each capable of patterning about 10 wafers per hour, can match this throughput.

[0005] The efficient delivery of substrates to be exposed to each lithography machine and retrieval of exposed substrates from each lithography machine is a critical factor in maximizing throughput of the system as a whole.

BRIEF SUMMARY OF THE INVENTION

[0006] It is an object of the invention to provide a method of processing substrates in a lithography system unit of a lithography system, the lithography system unit comprising at least two substrate preparation units, a load lock unit comprising at least first and second substrate positions, and a substrate handling robot for transferring substrates between the substrate preparation units and the load lock unit. The method comprises providing a sequence of substrates to be exposed to the robot, including an Nth substrate, an N-1th substrate immediately preceding the Nth substrate, and an N+1th substrate immediately following the Nth substrate; transferring the Nth substrate by means of the robot to a first one of the substrate preparation units; clamping the Nth substrate on a first substrate support structure in the first substrate preparation unit, the Nth substrate and first substrate support structure together forming a clamped Nth substrate; transferring the clamped Nth substrate by means of the robot from the first substrate preparation unit to an unoccupied one of the first and second positions in the load lock unit for exposure in the lithography system unit; and exposing the clamped Nth substrate in the lithography system unit. The clamped Nth substrate is preferably transferred to the load lock unit before exposure of the N-1th substrate in the lithography system unit is completed.

[0007] The method may further comprise transferring the N+1th substrate by means of the robot to a second one of the substrate preparation units; clamping the N+1th substrate on a second substrate support structure in the second substrate preparation unit, the N+1th substrate and second substrate support structure together forming a clamped N+1th substrate; and transferring the clamped N+1th substrate by means of the robot from the second substrate preparation unit to an unoccupied one of the first and second positions in the load lock unit for exposure in the lithography apparatus. The clamped N+1th substrate is preferably transferred to the load lock unit before exposure of the Nth substrate in the lithography system unit is completed.

[0008] The method may further comprise transferring the exposed clamped Nth substrate, by means of the robot, from a different one of the first and second positions of the load lock than occupied by the clamped N+1th substrate, to the second substrate preparation unit; separating the exposed Nth substrate from the first substrate support structure in the second substrate preparation unit; and transferring the exposed Nth substrate by means of the robot from the second substrate preparation unit for removal from the lithography system unit;

wherein the clamped N+1th substrate is transferred to the load lock unit before the exposed clamped Nth substrate is transferred from the load lock unit.

[0009] The lithography system unit may further comprise a substrate storage unit, and the method may further comprise transferring the Nth substrate by means of the robot to the substrate storage unit, and transferring the Nth substrate to a first one of the substrate preparation units comprises transferring the Nth substrate by means of the robot from the substrate storage unit to a first one of the substrate preparation units.

[0010] The lithography system unit may also comprise a substrate interface unit, the interface unit arranged for transfer of the substrates between a substrate delivery robot and the substrate handling robot. Transferring the Nth substrate to the substrate storage unit may comprise transferring the Nth substrate by means of the robot from the interface unit to the substrate storage unit, and transferring the exposed Nth substrate for removal from the lithography system unit may comprise transferring the exposed Nth substrate by means of the robot from the second substrate preparation unit to the interface unit for removal from the lithography system unit.

[0011] The lithography system may further comprise a horizontal transfer robot arranged for receiving the substrates and transferring them horizontally to the interface unit, and for transferring exposed substrates from the interface unit and transferring them horizontally for removal from the lithography system unit. The method may further comprise transferring the Nth substrate to the interface unit by means of the horizontal transfer robot prior to transferring the Nth substrate to the substrate storage unit; and transferring the exposed Nth substrate from the interface unit by means of the horizontal transfer robot after transferring the exposed Nth substrate to the interface unit by the substrate handling robot.

[0012] The first and second substrate preparation units and the first and second substrate positions of the load lock unit may be arranged vertically with respect to each other, and the substrate handling robot may be arranged for transferring the substrates vertically between the substrate preparation units and the first and second substrate positions of the load lock unit. In this configuration, the transferring steps of the method may comprise vertical transfers by the substrate handling robot.

[0013] The lithography system unit may further comprise a substrate storage unit and an interface unit. The first and second substrate preparation units, the first and second substrate positions of the load lock unit, the storage system, and the interface unit may be arranged vertically with respect to each other, and the substrate handling robot arranged for transferring the substrates vertically between the substrate preparation units, the first and second substrate positions of the load lock unit, the storage system, and the interface unit.

[0014] The method may further comprise transferring the exposed clamped N-1th substrate that was previously clamped to a third substrate support structure and exposed in the lithography apparatus, by means of the robot, from a different one of the first and second positions of the load lock than occupied by the clamped Nth substrate, to the first substrate preparation unit; separating the exposed N-1th substrate from the third substrate support structure in the first substrate preparation unit; and transferring the exposed N-1th substrate by means of the robot from the first substrate preparation unit for removal from the lithography system unit. The clamped Nth substrate may be transferred to the load lock unit before the exposure of the clamped N-1th substrate in the lithography apparatus is completed.

[0015] The method may further comprise, prior to clamping each of the substrates on one of the substrate support structures, pre-aligning the substrate towards a predetermined orientation in one of the substrate preparation units. The method may further comprise a coarse pre-alignment of each of the substrates towards a predetermined orientation before transfer to one of the substrate preparation units for clamping the substrate. The method may also further comprise, prior to clamping each of the substrates on one of the substrate support structures, thermal conditioning of the substrate support structure by removing heat energy from the substrate support structure.

[0016] The load lock may comprise a load lock robot, and the method may further comprise pumping down the load lock unit after transfer of the clamped Nth substrate to an unoccupied one of the first and second positions of the load lock unit; transferring the exposed clamped N-1th substrate, by means of the load lock robot arm, from the lithography system unit to an unoccupied one of the first and second positions of the pumped down load lock unit; transferring the clamped Nth substrate, by means of the load lock robot, from the pumped down load lock into the lithography system unit; and venting the load lock unit prior to transferring the exposed clamped N-1th substrate to the first substrate preparation unit.

[0017] The first and second positions of the pumped down load lock unit may be arranged vertically with respect to each other, and the load lock robot may comprise an upper handling body arranged for transferring substrates from and to the first position and a lower handling body arranged for transferring substrates from and to the second position.

[0018] It will be evident that the presently invented principle may be set into practice in various manners.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] Various aspects of the invention will be further explained with reference to embodiments shown in the drawings wherein:

[0020] FIG. 1 is a simplified schematic drawing of an embodiment of a charged particle lithography apparatus;

[0021] FIG. 2 is a simplified block diagram of a modular lithography apparatus;

[0022] FIG. 3a shows a top view of a layout of lithography system;

[0023] FIG. 3b schematically shows a cross-sectional side view of a portion of the lithography system of FIG. 3a;

[0024] FIG. 3c schematically shows a side view of another portion of the lithography system of FIG. 3a;

[0025] FIG. 4 schematically shows a lithography system unit within a clustered charged particle lithography system;

[0026] FIG. 5 schematically shows an exemplary trajectory of a substrate handling robot in a lithography system unit;

[0027] FIG. 6 shows a clustered lithography system;

[0028] FIG. 7 shows a portion of the clustered lithography system with its cover removed;

[0029] FIGS. 8a, 8b show an interface between a substrate transfer system and a preparation system at different stages of substrate transfer;

[0030] FIGS. 9a, 9b schematically show a carrier according to an embodiment of the invention;

[0031] FIG. 10 schematically shows a clamped substrate handling unit for use in a load lock system;

[0032] FIG. 11 shows a substrate preparation unit for placement of a substrate support structure onto which a substrate is to be clamped;

[0033] FIG. 12 schematically shows a clamped substrate handling robot for use in a load lock system;

[0034] FIG. 13a shows the transfer of a clamped substrate from a substrate preparation unit towards a load lock system;

[0035] FIG. 13b shows a more detailed view of the load lock system depicted in FIG. 13a;

[0036] FIGS. 14a, 14b schematically show the transfer of a processed clamped substrate from the load lock system towards a substrate preparation unit; and

[0037] FIGS, 15a, 15b show two different stages of a replacement of clamped substrates within a load lock system.

DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

[0038] The following is a description of various embodiments of the invention, given by way of example only and with reference to the drawings.

[0039] FIG. 1 shows a simplified schematic drawing of an embodiment of a charged particle lithography apparatus **100**. Such lithography systems are described for example in U.S. Patent Nos. 6,897,458 and 6,958,804 and 7,019,908 and 7,084,414 and 7,129,502, U.S. patent application publication no. 2007/0064213, and co-pending U.S. patent applications Serial Nos. 61/031,573 and 61/031,594 and 61/045,243 and 61/055,839 and 61/058,596 and 61/101,682, which are all assigned to the owner of the present invention and are all hereby incorporated by reference in their entirety.

[0040] In the embodiment shown in FIG. 1, the lithography apparatus **100** comprises an electron source **101** for producing an expanding electron beam **120**. The expanding electron beam **120** is collimated by collimator lens system **102**. The collimated electron beam **121** impinges on an aperture array **103**, which blocks part of the beam to create a plurality of beamlets **122**. The system generates a large number of beamlets **122**, preferably about 10,000 to 1,000,000 beamlets.

[0041] The electron beamlets **122** pass through a condenser lens array **104** which focuses the electron beamlets **122** in the plane of a beam blanker array **105**, comprising a plurality of blankers for deflecting one or more of the electron beamlets. The deflected and undeflected electron beamlets **123** arrive at beam stop array **108**, which has a plurality of apertures. The beamlet blanker array **105** and beam stop array **108** operate together to block or let pass the beamlets **123**. If beamlet blanker array **105** deflects a beamlet, it will not pass through the corresponding aperture in beam stop array **108**, but instead will be blocked. But if beamlet blanker array **105** does not deflect a beamlet, then it will pass through the corresponding aperture in beam stop array **108**, and through beam deflector array **109** and projection lens arrays **110**.

[0042] Beam deflector array **109** provides for deflection of each beamlet **124** in the X and/or Y direction, substantially perpendicular to the direction of the undeflected beamlets, to scan the beamlets across the surface of target or substrate **130**. Next, the beamlets **124** pass through projection lens arrays **110** and are projected onto substrate **130**. The projection lens arrangement preferably provides a demagnification of about 100 to 500 times. The beamlets **124** impinge on the surface of substrate **130** positioned on moveable stage **132** for carrying the substrate. For lithography applications, the substrate usually comprises a wafer provided with a charged-particle sensitive layer or resist layer.

[0043] The charged particle lithography apparatus **100** operates in a vacuum environment. A vacuum is desired to remove particles which may be ionized by the charged particle beams and become attracted to the source, may dissociate and be deposited onto the machine components, and may disperse the charged particle beams. A vacuum of at least 10^{-6} bar is typically required. In order to maintain the vacuum environment, the charged particle lithography system is located in a vacuum chamber **140**. All of the major elements of the lithography apparatus **100** are preferably housed in a common vacuum chamber, including the charged particle source, projector system for projecting the beamlets onto the substrate, and the moveable stage.

[0044] In an embodiment the charged particle source environment is differentially pumped to a considerably higher vacuum of up to 10^{-10} mbar. In such embodiment, the source may be located in a separate chamber, i.e. a source chamber. Pumping down the pressure level in the source chamber may be performed in the following way. First, the vacuum chamber and the source chamber are pumped down to the level of the vacuum chamber. Then the source chamber is additionally pumped to a desired lower pressure, preferably by means of a chemical getter in a manner known by a skilled person. By using a regenerative, chemical and so-called passive pump like a getter, the pressure level within the source chamber can be brought to a lower level than the pressure level in the vacuum chamber without the need of a vacuum turbo pump for this purpose. The use of a getter avoids the interior or immediate outside vicinity of the vacuum chamber being submitted to acoustical and/or mechanical vibrations as would be the case if a vacuum turbo pump or similar would be used for such a purpose.

[0045] FIG. 2 shows a simplified block diagram illustrating the principal elements of a modular lithography apparatus **200**. The lithography apparatus **200** is preferably designed in a modular fashion to permit ease of maintenance. Major subsystems are preferably constructed in self-contained and removable modules, so that they can be removed from the lithography apparatus with as little disturbance to other subsystems as possible. This is particularly advantageous for a lithography machine enclosed in a vacuum chamber, where access to the machine is limited. Thus, a faulty subsystem can be removed and replaced quickly, without unnecessarily disconnecting or disturbing other systems.

[0046] In the embodiment shown in FIG. 2, these modular subsystems include an illumination optics module **201** including the charged particle beam source **101** and beam collimating system **102**, an aperture array and condenser lens module **202** including aperture array **103** and condenser lens array **104**, a beam switching module **203** including beamlet blanker array **105**, and projection optics module **204** including beam stop array **108**, beam deflector array **109**, and projection lens arrays **110**. The modules are designed to slide in and out from an alignment frame. In the embodiment shown in FIG. 2, the alignment frame comprises an alignment inner subframe **205** and an alignment outer subframe **206**. A frame **208** supports the alignment subframes **205** and **206** via vibration damping mounts **207**. The substrate **130** rests on substrate support structure **209**, which is in turn placed on a chuck **210**. The chuck **210** sits on the stage short stroke **211** and long stroke **212**. The lithography machine is enclosed in vacuum chamber **240**, which may include a mu metal shielding layer or layers **215**. The machine rests on base plate **220** supported by frame members **221**.

[0047] Each module requires a large number of electrical signals and/or optical signals, and electrical power for its operation. The modules inside the vacuum chamber **240** receive these signals from control systems which are typically located outside of the chamber **240**. The vacuum chamber **240** includes openings, referred to as ports, for admitting cables carrying the signals from the control systems into the vacuum housing while maintaining a vacuum seal around the cables. Each module preferably has its collection of electrical, optical, and/or power cabling connections routed through one or more ports dedicated to that module. This enables the cables for a particular module to be disconnected, removed, and replaced without disturbing cables for any of the other modules.

[0048] FIG. 3a shows a top view of a layout of lithography system **300** comprising a group of lithography system units according to an embodiment of the invention. Hereinafter, the layout may be referred to as lithography system **300** or cluster **300**. FIG. 3b schematically shows a cross-sectional side view of a portion of the lithography system **300**.

[0049] In this particular embodiment, the lithography system **300** comprises a group of ten lithography system units. The lithography system units are arranged back-to-back in two rows of five. Directly adjacent to the cluster **300**, floor space is reserved as service area **305**. Each lithography system unit comprises a lithography apparatus **301** that is contained in its own vacuum chamber, with one side of each vacuum chamber facing a lithography system unit in the other row, while the opposing side faces the surroundings of the cluster **300**, in particular the service area **305**.

[0050] In case of a charged particle lithography apparatus, the vacuum chamber preferably comprises all elements that enable lithography processing, including a charged particle source, a projector system for projecting charged particle beamlets onto a substrate to be patterned, and a moveable substrate stage. For example, the vacuum chamber may correspond to the chamber **240** discussed with reference to FIG. 2.

[0051] The side of the lithography system unit facing a free area provided for service purposes comprises a load lock system **310** for transferring substrates into and out of the vacuum chamber, and also comprises an access door **330** that can be opened for such service purposes.

[0052] The lithography system units are provided with a door **330** at the same side as the load lock system **310**. The door **330** may be removably attachable, and may be removable in its entirety, for example by using a transfer unit **340**. The transfer unit **340** may be arranged to support the door **330** and may comprise one or more transfer elements **345**, such as wheels or rails. The lithography apparatus **301** may be supported by a supporting structure **335** for positioning the lithography apparatus at an elevated position.

[0053] The free area at the side at which the load lock system and access door are located preferably is sufficiently large to accommodate the footprint of the door and the load lock. Furthermore, it is desirable that the free area is sufficiently large to accommodate a footprint of an arrangement for carrying components of the lithography apparatus.

[0054] The lithography system **300** thus comprises a plurality of lithography system units having a load lock system **310** and a door **330** facing the surroundings, more in particular facing the service area **305** surrounding the lithography system **300**. Due to the "outward" orientation of the load lock systems **310** and doors **330**, the lithography system units, including the lithography apparatuses **301** within the vacuum chambers, are directly accessible from the service area **305**. Direct access simplifies servicing of the lithography system **300**, and may reduce the downtime of the lithography system or parts thereof. Opening a single specific vacuum chamber for servicing can be done without affecting the throughput of other lithographic system units within the lithography system **300**.

[0055] The back-to-back layout of the lithography system units provides a lithography system **300** with a limited "footprint". Floor space within a fab is valuable, and efficient use of the fab floor space is thus important.

[0056] The load lock system **310** may be integrated into the door **330**. Integration of the load lock system **310** and the door **330** reduces the amount of material used in manufacturing the lithography system unit. A portion of the door **330** may be directly used as one of the side walls of the load lock system **310**. The material reduction has the advantage that the door and load lock system combination is easier to handle during servicing. Furthermore, as less material is needed during manufacturing, the costs of manufacturing the lithography system are reduced as well.

[0057] The lithography system **300** further comprises a substrate supply system **315**. The substrate supply system **315** is arranged to receive substrates to be processed by the lithography system **300**, and to provide these substrates to the lithography system units for processing. This can effectively mean that the substrate supply system **315** provides the substrates to a preparation system **320** for pre-processing purposes. After patterning, the substrate supply system **315** may collect the patterned substrates. The use of a substrate supply system **315** enables the lithography system **300** to efficiently cooperate with other equipment in the fab as it allows for a relatively easy replacement of presently used lithography systems.

[0058] FIG. 3c schematically shows another side view of the lithography system **300** of FIG. 3a. In the shown embodiment, the lithography system **300** further comprises a substrate transfer system **350** for receiving substrates from and/or sending substrates to the substrate supply system **315**. The substrate transfer system **350** may take the form of a suitable conveyor system, for example a conveyor system which extends in a substantially horizontal direction.

[0059] Preferably, the substrate transfer system **350** is designed not to interfere with the doors **330** of the lithography system units. This may be accomplished as shown in FIG. 3c. In this embodiment the substrate transfer system **350** extends in a substantially horizontal direction, and is arranged above the load lock systems **310**, as well as the preparation units **320**, of the lithography system units. As a result, the door of a single lithography system unit within the lithography system **300** may be opened for servicing purposes while the substrate transfer system **350** can continue with the transfer of substrates between the substrate supply system **315** and the other lithography system units within the lithography system **300**.

[0060] The layout described with reference to FIGS. 3a-3c provides a cluster of lithography system units with limited complexity. The layout can be scaled rather easily. For example, if the lithography system **300** needs to operate with an 80% capacity, only eight out of the ten lithography system units need to be operational and/or installed.

[0061] Furthermore, the lithography system **300** can provide a reliable throughput. If one lithography system unit malfunctions and/or needs servicing, the other lithography system units within the cluster **300** may continue their operation. As a result, in case of 10 lithography system units with a throughput of 10 substrates, or wafers, per hour (wph), malfunctioning of one lithography system unit allows the cluster **300** to continue to work with a 90% efficiency. That is, it then operates with a throughput of 9 x 10 wph = 90 wph instead of the ideal 100 wph. In comparison, a state of the art optical lithography apparatus may operate with a throughput of 100 wph. However, if some component within such optical lithography apparatus malfunctions, the entire apparatus needs to be shut down, reducing the throughput to 0 wph.

[0062] Before entry into the vacuum chamber, a substrate typically undergoes the actions of clamping, pre-alignment and pump down. In this context, clamping is defined as providing a substrate on a substrate support structure to form a single structure, hereafter referred to as "clamp". Furthermore, the term "clamped substrate" is used to refer to a substrate being clamped to a substrate support structure. Pre-alignment relates to aligning the substrate and/or clamp such that patterning can be performed onto a predetermined portion of the substrate in a certain orientation. Pump down relates to the step of reducing the pressure surrounding the substrate to minimize contamination and to reduce the influence of the substrate on the vacuum chamber pressure upon insertion into the lithography apparatus **301**.

[0063] After the patterning action performed by the lithography apparatus **301**, the substrate is typically exposed to a venting action, and an unclamping action, i.e. separating the substrate from the substrate support structure. In between the venting and unclamping actions, the substrate may be transferred.

[0064] The load lock system **310** forms an interface to a vacuum environment within the vacuum chamber. The system **310** is typically used for the pump down action and the venting action described above. For this purpose, the load lock system **310** comprises one or more chambers in which the pressure can be regulated. The load lock system **310** may comprise a single chamber suitable for both pump down and venting actions. Alternatively the system **310** comprises separate chambers for pump down and venting. For the pump down action the system **310** comprises pumps for pumping down the pressure within a chamber to a reduced pressure, e.g. a vacuum suitable for transfer of the clamped substrate and substrate support to the lithographic apparatus **301**. For the venting action the load lock system **310** comprises vents for venting a chamber to increase the pressure after processing of the clamped substrate in the lithographic apparatus **301**.

[0065] Clamping and/or unclamping may be performed in the preparation systems **320**. Alternatively, the clamping may be performed at a different location prior to providing the substrate to the preparation systems **320**, for example within the common supply system **315**. In yet another alternative, clamping and/or unclamping may be performed within the load lock system **310**.

[0066] Clamping and unclamping may be performed in separate units, but may also be executed in the same unit. Hereinafter the expression "clamping unit" refers to a unit for clamping and/or unclamping.

[0067] FIG. 4 schematically shows a lithography system unit provided with a first load lock chamber **310a** for pump down, a second load lock chamber **310b** for venting and a preparation system **320** that includes a number of substrate preparation units **360a-360d**. In this embodiment, a clamp is formed in a suitable substrate preparation unit **360a-360d** in the preparation system **320** and then inserted into the vacuum chamber via the first load lock chamber **310a**. After patterning of the substrate by the lithography apparatus **301**, the clamp is transferred back to a suitable substrate preparation unit **360a-d** in the preparation system **320** via the second load lock chamber **310b** for unclamping.

[0068] As shown in the embodiment of FIG. 4, the preparation system **320** may further include a pre-alignment unit **370** for pre-aligning the substrate before entry into the lithography apparatus **301** via the first load lock chamber **310a**. Pre-alignment may be needed to ensure that the position and/or orientation of the substrate on the substrate support structure are suitable for accurate exposure within the lithography apparatus **301**. After pre-alignment in the pre-alignment unit **370** the substrate is provided to the first load lock chamber **310a** for further processing.

[0069] Pre-alignment may be performed on an individual substrate before the substrate is clamped. In such case the pre-alignment may be done within a substrate preparation unit **360a-360d**, which would reduce the space being occupied by the lithography system unit. In case the substrate is pre-aligned in a separate pre-alignment unit **370** the substrate is preferably pre-aligned while being clamped onto a substrate support structure. Pre-alignment of the clamped substrate reduces the required accuracy at which the substrate is clamped onto the substrate support structure.

[0070] A preparation system **320** may further comprise one or more additional units. For example, the preparation system **320** may include a conditioning unit for conditioning clamped substrates and/or unclamped substrates prior to exposure in the lithography apparatus **301**. The conditioning unit may be arranged for thermal conditioning of a clamped or unclamped substrate by e.g. removing heat energy from the substrate (and substrate support structure) to improve the accuracy of lithographic patterning, as is known to persons skilled in the art.

[0071] Substrates and/or clamps may be transferred between different units by using a robot that operates within a robot space **400**. In the exemplary embodiment of FIG. 4 the robot comprises a carrier **401** that can move in a substantially vertical direction. Therefore, such robot will hereafter be referred to as vertical transfer robot or VTR. The carrier **401** is arranged for suitably transporting substrates and/or clamps between the load lock chambers **310a, 310b**, the substrate preparation units **360a-360d**, and the pre-alignment unit **370**. In addition, the robot **401** may further be arranged to handle substrate exchange with the substrate transfer system **350**. In FIG. 4 the carrier **401** carries a clamp comprising a substrate support structure **403** with a substrate **405** clamped thereon.

[0072] A lithography system unit may further comprise a storage unit **410** for temporarily storing substrates. The stored substrate may be substrates that still need to be patterned by the lithography apparatus **301**. Alternatively or additionally, the substrate storage unit **410** may be arranged to store patterned substrates awaiting transfer via the substrate transfer system **350**. In the embodiment shown in FIG. 4, the storage unit **410** is coupled to the substrate transfer system **350**. Alternatively, or additionally, the storage unit **410** may be coupled to a replaceable unit and may take the form of a so-called front opening unified pod (FOUP). FOUPs enable relatively safe transfer of several substrates in one FOUP in a (clean room) environment. In yet another embodiment, the storage unit **410** is a replaceable unit, for example a FOUP.

[0073] Additionally, FIG. 4 schematically shows that electronics **420** needed to ensure proper operation of the lithography apparatus **420** may be placed on top of the lithography apparatus **301**. Just like the embodiment shown in FIG. 3b, the door **330** can be removed together with the other components outside the vacuum chamber, for example by means of a transfer unit **340** comprising one or more transfer elements **345**.

[0074] Although different components in FIG. 4 are shown on top of each other, alternative embodiments in which one or more of the components are positioned adjacent to each other in a substantially horizontal direction are envisioned as well. Furthermore, the order of the different components may be different.

[0075] In other embodiments of the lithography system, not shown in FIG. 4, clamping and/or unclamping is performed within the load lock system **310**. Load lock systems **310** that are capable of executing these actions then need to be rather sophisticated in nature.

[0076] Clamping methods include but are not limited to clamping by using capillary forces, for example as described in US patent application 2010/0265486 assigned to the owner of the present invention and hereby incorporated by reference in its entirety. Clamping by applying a vacuum, clamping by freezing the substrate to the substrate support structure, and clamping by the use of electromagnetic forces are some of the possible alternatives. The type of clamping may depend on the type of subsequent processing to be used on the substrate.

[0077] The load lock systems **310a**, **310b**, as well as other units within the lithography system, for example one or more units in the preparation systems **320**, such as pre-alignment units **370**, clamping/unclamping units **360** and substrate storage systems **410** may comprise one or more valves for creating a controlled pressure environment. Keeping the substrates and/or clamps in a controlled pressure environment permits a reduced contamination environment to be maintained around the substrates. The controlled pressure environment may be an intermediate vacuum, between atmospheric pressure and the high vacuum of the lithography apparatus **301**. This intermediate vacuum enables a reduction of contamination while avoiding having a large volume maintained at a high vacuum. In particular in case of not yet patterned substrates the intermediate vacuum aids in preparing the substrate for later processing in the vacuum environment of the lithography apparatus.

[0078] A lithography system where the clamping and/or unclamping units are provided within the lithography system units, for example within a preparation system **320** as shown in FIG. 4 or within a load lock system **310**, may be identified as a clustered lithography system **300** with a localized unclamped substrate supply or "localized cluster". In a localized cluster unclamped substrates are transported to an area in close proximity of the lithography apparatus **301** in which they are to be processed. Then, the substrates are clamped on a substrate support structure, and finally the clamps, i.e. substrates clamped onto a substrate support structure, are provided to the lithography apparatus **301**. Because not many components are shared between the different lithography system units, localized clusters can be scaled relatively easy, as addition and/or removal of a lithography system unit merely means that, at most, adjustments have to be made to way substrates are provided.

[0079] FIG. 5 schematically shows an action flow for processing a substrate in a lithography system unit. Transfer of the substrate may be accomplished using a substrate handling robot, FIG. 5 illustrating the trajectory of the robot for making the sequence of transfers. The robot may comprise and/or take the form of a carrier such as carrier **401** in FIG. 4. In FIG. 5, the interface between the substrate transfer system and the robot is denoted by "IF". Furthermore, the exemplary lithography system unit comprises a storage unit SU, a first preparation system unit PSU-1, a second preparation system unit PSU-2, and a load-lock LL coupled to a lithography apparatus.

[0080] As mentioned earlier, the interface IF may correspond to the interface between the substrate transfer system **350** and the lithography system unit described above with reference to FIG. 4. The storage unit SU may correspond to the storage unit **410** described above with reference to FIG. 4. The preparation units PSU-1 and PSU-2 may for example comprise two of the substrate preparation units **360** described above. Finally, the load lock LL may correspond to the load lock system **310** described above with reference to FIG. 4. Alternatively, the load lock LL may comprises a single load lock chamber comprising one or more carriers to enable the handling of more than one substrate in the load lock LL. Movements during which the robot actually transfers a substrate are represented by the solid arrows. Mere movements of the robot without substrate transfer are denoted by the dashed arrows.

[0081] The trajectory in FIG. 5 starts with the robot being positioned at the interface IF. The first movement involves the transfer of a new unclamped substrate to be exposed from the interface IF towards the storage unit SU for temporary storage in action **501**. Note that prior to such transfer in action **501** the substrate may have been aligned in a relatively coarse manner, for example by detection of the orientation of a substrate notch or the like. After placement of the substrate in the storage unit SU, the robot moves towards the first preparation system unit PSU-1 in action **502**. At preparation system unit PSU-1, the robot picks up an exposed unclamped substrate and transfers this substrate in action **503** to the interface IF to allow removal thereof from the lithography system unit. The robot then moves back in action **504** to storage unit SU to pick up the unclamped substrate for exposure placed therein at the end of action **501**. In action **505**, the unclamped substrate is picked up from the storage unit SU and transferred to the preparation system unit PSU-1. After placement of the unclamped substrate in the PSU-1, the robot moves in action **506** to the preparation system unit PSU-2. The robot then picks up a clamped substrate to be exposed and transfers the clamped substrate to the load lock LL for exposure in the lithography apparatus in action **507**.

After removal of the clamped substrate at the load lock, the robot picks up an exposed clamped substrate and transfers this substrate to preparation system unit PSU-2 for unclamping in action **508**. Finally, the robot moves to the interface IF without carrying a substrate in action **509**. The series of actions **501-509** is referred to as "cycle A".

[0082] The trajectory in FIG. 5 then continues at the interface IF with action **511**, which is similar to action **501**. However, after placement of the new unclamped substrate to be exposed, the robot does not move to preparation system unit PSU-1 as in action **502**, but instead moves to preparation system unit PSU-2 in action **512**. Subsequently, in action **513**, the robot picks up an exposed clamped substrate present in preparation system unit PSU-2, and transfers this substrate to the interface IF to enable removal of the substrate from the lithography system unit. The robot then moves to the storage unit SU in action **514** in a similar fashion as it did in action **504**. The robot then picks up an unclamped substrate to be exposed from the storage unit SU and transfers this substrate to the preparation system unit PSU-2 in action **515**. After delivery of this unclamped substrate, the robot moves to the preparation system unit PSU-1 in action **516**, picks up a clamped substrate to be exposed and transfers the clamped substrate to the load lock LL for exposure in the lithography apparatus in action **517**. After removal of the clamped substrate at the load lock, the robot picks up an exposed clamped substrate and transfers this substrate to preparation system unit PSU-1 for unclamping in action **518**. Finally, the robot moves to the interface IF without carrying a substrate in action **519**. The series of actions **511-519** is referred to as "cycle B".

[0083] The robot may now repeat the trajectory of FIG. 5, which effectively means that it alternates between following cycle A and cycle B, where the difference between the two cycles is the role of the preparation system unit PSU-1 and the preparation system unit PSU-2. The trajectory shown in FIG. 5 is particularly useful to ensure a continuous flow of substrates in case the clamping action in a preparation system unit takes more time than the duration of an entire cycle.

[0084] In view of the desire to have a lithography system of limited size, the storage capacity of the components within the lithography system unit is preferably limited. In particular, PSU-1 and PSU-2 are generally only capable of facilitating the preparation of a single substrate. Similarly, the storage unit SU preferably stores a single substrate. The load lock LL is preferably capable of storing two substrates clamped onto corresponding substrate support structures. The possibility to accommodate two clamped substrates in the load lock LL enables placement of a clamped substrate in the load lock LL without the need to first remove a substrate that has been processed earlier. The load lock LL may comprise a single load lock chamber. Alternatively, the load lock LL comprises more than one load lock chamber, for example as described with reference to FIG. 4. In this multiple-chamber embodiment, each load lock chamber is preferably arranged to accommodate a single substrate clamped onto a substrate support structure.

[0085] In case only single substrates are stored in the storage unit SU, the preparation system unit PSU-1 and the preparation system unit PSU-2, the following could be said with respect to a wafer N that is processed following the trajectory as described with reference to FIG. 5. The wafer N would be transferred from the interface IF to the storage unit SU in action **501**, optionally after the orientation of the wafer has been changed as a result of an alignment procedure at the interface IF. The wafer N is then transferred to the first preparation system unit PSU-1 in action **505**. In case of the use of a storage unit SU with a capacity of a single wafer, the storage unit SU would thus then be empty. The wafer N is then clamped and the clamped substrate is then transferred to the load lock LL in accordance with action **517**. Besides clamping, other actions may also be performed in the preparation system unit PSU-1. For example, relatively fine alignment, in particular with respect to the orientation of the wafer N with respect to the substrate support structure onto which the wafer N is to be clamped, may be executed a brief period of time prior to clamping. Via the load lock LL the wafer N is transferred into the lithography apparatus for lithographic exposure. Within the lithography apparatus one or more further actions may be performed prior to exposure. Such actions may include one or more measurements such as alignment mark measurement, beam positioning measurement, and beam current measurement. Actions related to such measurement may include, but are not limited to movement of the wafer N to a focal plane sensor, measure global orientations in different directions such as x, y, z, Rx, Ry and Rz, scan marks around fields on the wafer N, movement of the wafer N to marks, such as knife edge alignment marks, on an alignment sensor, and movement of the wafer N to a beam positioning sensor. After exposure, the wafer N is transferred back to the load lock chamber LL and removed by the robot and transferred to a preparation system unit for unclamping corresponding to action **508** or action **518** depending on the preparation system unit that is being used. Finally, the wafer N is moved to the interface in action **509** or action **519** to enable removal of the processed wafer N from the lithography system unit by the substrate transfer system.

[0086] In the scenario described above, the wafer that is to be processed after wafer N, i.e. wafer N+1, occupies the place left open by wafer N in the storage unit SU as a result of the robot transferring wafer N+1 from the interface IF to the storage unit SU in action **511**. The substrate is then moved to the preparation system unit PSU-2 in action **515**. After preparation, the wafer N+1 is transferred to the load lock LL. Preferably, at this time, wafer N is also present in the load lock LL, ready to be removed from the load lock, and to be transferred to preparation system unit PSU-2 by the robot in action **508**. In such scenario, wafer N would thus effectively takes the place previously occupied by wafer N+1 in the preparation system unit PSU-2.

[0087] In the scenario described above, the wafer that is processed prior to wafer N, i.e. wafer N-1, is the wafer that resides in the load lock LL when wafer N is placed therein as a result of action **517**. Wafer N-1 is then removed from the load lock LL and transferred to the substrate preparation unit PSU-1 in action **518** to take the place previously occupied by wafer N.

[0088] FIG. 6 shows a perspective view of a lithography system **300**. In such lithography system **300** all components may be protected from the outside environment by means of a suitable housing or casing **600**. The housing **600** includes removable portions, or may be removable in its entirety, to facilitate maintenance, repair, and operational adjustment of components within the lithography system **300**. The housing **600** may be provided with one or more interfaces that allow operators to monitor and/or adjust parameters within the lithography system **300**. The interfaces may comprise a display **610** and/or a keyboard **620** for these purposes.

[0089] FIG. 7 shows a portion of the clustered lithography system of FIG. 6 with a portion of its cover being removed. FIG. 7 shows elements used for transfer and preparation of substrate for five lithography system units. The substrates are provided via the substrate transfer system **350** comprising a transfer robot **650** that moves in a substantially horizontal direction, hereafter referred to as horizontal transfer robot or HTR **650**. The HTR **650** is arranged to transfer substrates to be processed towards a lithography system unit and to transfer processed substrate away from a lithography system unit. An exchange of substrates between the substrate transfer system **350** and the lithography system unit is performed via an interface **640**.

[0090] Each lithography system unit is further provided with at least two substrate preparation units **360**, a storage unit **410** and a load lock **310** arranged for accommodation of at least two substrates or clamps. The lithography system unit further includes a carrier **401** for moving substrates and/or clamps between the different units, for example following a trajectory as discussed with reference to FIG. 5. Since the carrier **401** will move in a substantially vertical direction, hereafter the carrier may be referred to as vertical transfer robot or VTR **401**.

FIGS. 8a, 8b provide a more detailed view of the interface **640** between the substrate transfer system **350** and a lithography system unit at different stages of substrate transfer. The interface **640** comprises a chamber **641** provided with a top wall provided with an opening **642** that is sufficiently large to allow a substrate **405** to be transferred through the opening **642**. The chamber **641** further includes a supporting surface **643** and at least three extendible pins **644**. The at least three extendible pins **644** are positioned in the supporting surface **643** and can move in a substantially vertical direction. The pins **644** are placed with respect to each other in such a way that they can support a substrate **405** in a stable manner. Furthermore, the pins **644** are positioned in a way that they do not interfere with HTR **650** and VTR **401** so that these robots may transfer the substrate **405** without being hindered by the pins **644**.

[0091] The HTR **650** comprises a body **651** that can move along a guiding rail **652**. The body **651** is provided with two opposing support units **653** that may be provided with one or more extensions or "fingers". The two opposing support units **653** are arranged for holding the substrate **405** in a stable position. The HTR **650** is constructed in such a way that its components do not interfere with the pins **644** while being positioned at the edge of the opening **641** to enable substrate transfer between the HTR **650** and the lithography system unit.

[0092] Supply of a substrate **405** to a lithography system unit may be performed in the following way. First the HTR **650** is provided with a substrate **405** that rests on top of the supporting units **653**. The HTR **650** then transfers the substrate **405** by movement of the body **651** in a substantially horizontal direction along a guiding rail **652** until the substrate **405** is positioned above the opening **461**. It will be understood that the HTR **650** can take many different forms and the means of moving the HTR **650** may well be different from the way depicted in FIGS. 8a, 8b. Subsequently, the pins **644** will move upward through the hole until they engage with the substrate **405**. At that point the pins **644** will move upwards somewhat further to lift the substrate **405** from the supporting units **653** of the HTR **650**. The HTR **650** is then moved away from the opening **641** as depicted in FIG. 8b. Finally, the pins **644** are lowered such that the substrate **405** enters the interface chamber **461**. The end position of the pins **644** is determined by the specific size and shape of the VTR **401** that is used in the lithography system unit. Removal of a substrate **405** from a lithography system unit may be performed by performing the actions described above in a reverse order.

[0093] FIGS. 9a, 9b schematically show a carrier **401** according to an embodiment of the invention. The carrier **401** comprises a body **680** provided on a robot arm comprising a base **681a** that can be moved along a rail **683**, the rail being oriented in a substantially vertical direction. The robot arm **681** further comprises different sections **681b**, **681c**, which enable the arm to translate and rotate the substrate in a two-dimensional plane, typically the substantially horizontal plane. The body **680** is provided with at least two extended portions or fingers **684a**, **684b** for carrying a substrate **405**. Additionally, the body **680** is provided with at least two further extended portions or fingers **685a**, **685b** for carrying a substrate support structure **403** onto which a substrate **405** may be clamped. Preferably, the fingers **684a**, **684b** for carrying a substrate **403** are positioned at a level below the fingers **685a**, **685b**. Preferably, the difference in height exceeds the thickness of the substrate support structure **403** to ensure that the fingers **684a**, **684b** do not hamper the carrying performance of the fingers **685a**, **695b**. In an optimal design, the fingers **684a**, **684b** may provide additional support in case a clamp is being transferred by the carrier **401**.

[0094] The fingers **684a**, **684b** preferably extend in a single direction, i.e. they take the form of straight bars. Most preferably, the fingers **684a**, **684b** extend in directions substantially parallel to each other. The fingers **685a**, **685b** preferably have an arched or crescent shape, the ends of the fingers **685a**, **685b** opposing each other. Both the fingers **684a**, **684b** and **685a**, **685b** have a length that is sufficiently long to extend underneath more than halfway the structure they are designed to support. In case of a circular shape, such length should thus exceed the radius of the structure to be carried.

[0095] The VTR **401** takes the substrate from the interface chamber **641** as discussed with reference to FIGS. 8a, 8b and transfers the substrate **405** to a substrate preparation unit **360** or storage unit **410**. In the latter case, as depicted in FIG. 10 by means of the dashed arrow, the VTR **401** transfers the substrate **405** from the substrate unit **410** to the substrate preparation unit **360** to enable clamping onto a substrate support structure and to perform other suitable preparation actions. The storage unit **410** comprises a supporting surface **411** and may include pins **414** that may be extended in a substantially vertical direction. In case of insertion or removal of a substrate the pins **414** are suitably extended to allow the fingers **684a**, **684b** that support the substrate **405** to slide past at least some of the pins **414** at a height lower than the pin ends. When the fingers **684a**, **684b** are in the correct position, i.e. prior to insertion such that the substrate **405** supported by the fingers **684a**, **684b** is suitably placed above the pins **414**, and prior to removal such that the fingers **648a**, **684b** are suitably placed underneath the substrate **405** supported by the pins **414**, the pins **414** move to allow transfer from the substrate **405** between the pins **414** and the fingers **684a**, **684b**.

[0096] In case of insertion, the pins **414** then move upwards until they are in sufficient contact with the substrate **405**. At that stage, either the pins **414** move upwards somewhat further or the VTR **401** is moved downwards to separate the substrate **405** from the VTR **401**, and allow the support of the substrate **405** to be entirely taken over by the pins **414**. After sufficient separation, the VTR **401** is retracted out of the storage unit **410**.

[0097] In case of substrate removal, the pins **414** move downwards until the fingers **684a** , **684b** of the VTR **401** are in sufficient contact with the substrate **405**. At that stage, either the VTR moves upwards or the pins **414** are moved downwards to separate the substrate **405** from the pins **414** and allow the support of the substrate **405** to be entirely taken over by the VTR **401**. After sufficient separation, the VTR **401** is retracted out of the storage unit **410**.

[0098] FIG. 11 shows a substrate preparation unit **360** in which a substrate support structure **403** is placed onto which a substrate **405** is to be clamped. The substrate is supported on pins **364** that operate in a similar way as pins **414** discussed with reference to FIG. 10. Preferably, the substrate support structure **403** is provided with notches **361** that enable accommodation of the pins **364** within the substantially circular circumference of the substrate support structure **403** that would have been formed if such notches **361** would have been absent. The use of notches **361** limits the space that is occupied by the combination of substrate support structure **403** and pins **364**. Furthermore, by allowing the pins **364** to extend through the notches **361** the substrate **405**, when clamped onto the substrate support structure **403**, is in contact with the support structure **403** over a larger area which may improve the clamping quality. Finally, the use of notches in the substrate support structure may enable some form of coarse pre-alignment.

[0099] Clamping methods include but are not limited to clamping by using capillary forces, for example as described in US patent application 2010/0265486 assigned to the owner of the present invention and hereby incorporated by reference in its entirety. Clamping by applying a vacuum, clamping by freezing the substrate **405** to the substrate support structure **403**, and clamping by the use of electromagnetic forces are some of the possible alternatives. The type of clamping may depend on the type of subsequent processing to be used on the substrate

405. The supply of fluids, for example in case of clamping by using capillary forces, or removal of air, for example in case of clamping by applying a vacuum, may be executed via one or more tubes **365**. The surface of the substrate support structure **403** for receiving the substrate **405** may be provided with a pattern of grooves and/or other elevated structures such as burls, to enhance the clamping process.

[00100] The substrate support structure **403** is further provided with a number of protrusions or lips **362**. These lips **362** are positioned along the circumference of the substrate support structure **403**. The lips **362** are used to engage with the fingers **685a**, **685b** of the VTR **401**. In FIG. 11, the lips **362** are located at a height level that is close to the surface of the substrate support structure **403** onto which the substrate **405** is to be clamped. To enhance the stability during transfer the lips **362** are preferably located above the center of mass of the substrate support structure **403**, and preferably also above the center of mass of the combination of a substrate support structure **403** and a substrate **405** clamped thereon. In some embodiments, another lip **362** may be used to engage with the body **680** of the VTR **401**.

[00101] In some embodiments, such as the embodiment shown in FIG. 11, the substrate support structure **403** is provided with further protrusions or lips **363**, **366**. The at least two lips **366** (only one lip is depicted in FIG. 11) are provided at the same height level as the lips **362**. The lip **633** is provided at a lower height level. In the embodiment discussed hereafter, these lips **363**, **366** are used by a handling robot in the load lock system **310**.

[00102] Preferably, the lips **362** used to engage with the VTR fingers **685a**, **685b** are located along one side of the substrate support structure **403**, that side being the side facing away from the VTR body **680**. Such arrangement reduces the risk of tilt or tipping over during transfer.

[00103] In embodiments using the at least two lips **366** and at least one lip **363**, the at least two lips **366** are preferably located between the lips **362** used to engage with the VTR fingers **685a**, **685b**. The at least one lip **363** is located at the side facing the VTR body **680**.

[00104] FIG. 12 schematically shows a clamped substrate handling robot for use in a load lock system **310**. The handling robot receives clamped substrates to be processed from the VTR **401** via passage **710** and transfers the clamped substrate towards the lithography apparatus via passage **705** in door **330**. Similarly, the handling robot receives processed clamped substrates from the lithography apparatus via passage **705** and hands over the substrate to the VTR **401** entering via passage **710**.

[00105] The handling robot comprises a body **701** provided on a robot arm. The body **701** is provided with at least two extended portions or fingers **702a, 702b** for carrying a substrate support structure **403** onto which a substrate **405** is clamped. Preferably, the fingers **702a, 702b** have an arched or crescent shape, and have a length that is sufficiently long to extend underneath more than halfway the structure they are designed to support. The finger **702a** has a different, i.e. higher, height level than the finger **702b**. The reason for this difference in height level will be discussed with reference to FIG. 13b.

[00106] FIG. 13a shows the transfer of the clamped substrate from the substrate preparation unit **360** towards the load lock system **310**. The load lock system **310** comprises a clamped substrate handling robot comprising a robot arm **720** onto which two handling bodies **701a, 701b** are attached above each other.

[00107] FIG. 13b shows a more detailed view of the load lock system **310** at a time just after delivery of the clamped substrate to the upper handling body **701a**. In FIG. 13b, merely a portion of the robot arm **720** is shown, i.e. the portion that relates to the upper handling body **701a**. The robot arm **720** comprises a base **721a** that can be moved along a rail **721c**, the rail **721c** being oriented in a substantially vertical direction. The robot arm **720** further comprises different sections **721b**, connected to the base **721a** and the body **701a**, that enables the arm to translate and rotate the clamp that is being held by the fingers **702a, 702b** in a two-dimensional plane.

[00108] In the embodiment shown in FIG. 13b, the substrate support structure **403** is provided with lips **362** have been used to engage with the VTR fingers **685a, 685b** located along a side of the substrate support structure **403** facing away from the VTR body **680** (the left side in FIG. 13b). Furthermore, an additional lip **362** located on the other side of the substrate support structure **403** have been used to engage with the VTR body **680**. Furthermore, two lips **366** (only one shown) are used to engage with the upper finger **702a** extending from the upper body **701a** of the handling robot and the lip **363** is used to engage with the lower finger **702b** extending from the upper body **701a** of the handling robot such that the upper body **701a** is able to independently carry the substrate support structure **403**. The position of the fingers **702a, 702b** (one high, one low) in combination with the different orientation of the two sets of fingers **702a, 702b**, and **685a, 685b** with respect to each other (i.e. at an angle) allows both sets of fingers to hold the substrate support structure simultaneously without interfering with each other. As a result, if one of the sets of fingers is retracted, the substrate support structure **403** will be held by the other set of fingers. The

design of the respective handling robots, i.e. VTR **401** and clamped substrate handling robot in load lock system **310**, makes it possible to hand over a substrate support structure **403** in a direct way. Such handover reduces the space that is needed for substrate support structure transfer, which helps to keep the size of the lithography system unit as small as possible.

[00109] FIGS. 14a, 14b schematically show the transfer of a processed clamped substrate from the load lock system **310** towards a substrate preparation unit **360** by means of the VTR **401** (see dashed line). In FIG. 14a, the VTR **401** picks up the clamped substrate after handover with the lower handling body **701b** of the handling robot. In FIG. 14b, the VTR **401** places the clamped substrate in the substrate preparation unit **360** for unclamping.

[00110] The empty space left in the load lock system **310** may now be occupied by a processed clamp that is received from the lithography apparatus as shown in FIG. 15a. The clamped substrate to be processed that was recently put in (see FIG. 13b), may then be inserted into the lithography apparatus for processing as shown in FIG. 15b.

[00111] Alternatively, the clamped substrate to be processed (held by upper body **701a**) is entered into the lithography apparatus after removal of the processed clamped substrate. In such case, the lower body **701b** may not hold any clamped substrate until a new clamped substrate to be processed is provided by the VTR **401** or until the clamped substrate recently put in the lithography apparatus has been processed.

[00112] Although some embodiments of the invention have been described with reference to a lithography system comprising ten lithography system units, the number of lithography system units within a lithography system may vary. For example, instead of ten lithography system units, any other number of lithography system units above one may be used.

[00113] The invention has been described by reference to certain embodiments discussed above. It will be recognized that these embodiments are susceptible to various modifications and alternative forms well known to those of skill in the art without departing from the spirit and scope of the invention. Accordingly, although specific embodiments have been described, these are examples only and are not limiting upon the scope of the invention, which is defined in the accompanying claims.

CLAIMS

1. A method of processing substrates (405) in a lithography system unit (301) of a lithography system (300), the lithography system unit comprising at least two substrate preparation units (360), a load lock unit (310) comprising at least first and second substrate positions, and a substrate handling robot (401) for transferring substrates between the substrate preparation units and the load lock unit, wherein the method comprises:

providing a sequence of substrates (405) to be exposed to the robot, including an Nth substrate, an N-1th substrate immediately preceding the Nth substrate, and an N+1th substrate immediately following the Nth substrate;

transferring the Nth substrate (505) by means of the robot to a first one of the substrate preparation units;

clamping the Nth substrate on a first substrate support structure (403) in the first substrate preparation unit, the Nth substrate and first substrate support structure together forming a clamped Nth substrate;

transferring the clamped Nth substrate (517) by means of the robot from the first substrate preparation unit to an unoccupied one of the first and second positions in the load lock unit for exposure in the lithography system unit; and

exposing the clamped Nth substrate in the lithography system unit.

2. The method of claim 1, wherein the clamped Nth substrate is transferred (517) to the load lock unit before exposure of the N-1th substrate in the lithography system unit is completed.

3. The method of claim 1 or 2, further comprising:

transferring the N+1th substrate (515) by means of the robot to a second one of the substrate preparation units;

clamping the N+1th substrate on a second substrate support structure in the second substrate preparation unit, the N+1th substrate and second substrate support structure together forming a clamped N+1th substrate; and

transferring the clamped N+1th substrate (507) by means of the robot from the second substrate preparation unit to an unoccupied one of the first and second positions in the load lock unit for exposure in the lithography apparatus.

4. The method of claim 3, wherein the clamped N+1th substrate is transferred (507) to the load lock unit before exposure of the Nth substrate in the lithography system unit is completed.

5. The method of any one of the preceding claims, further comprising:

transferring the exposed clamped Nth substrate (508), by means of the robot, from a different one of the first and second positions of the load lock than occupied by the clamped N+1th substrate, to the second substrate preparation unit;

separating the exposed Nth substrate from the first substrate support structure in the second substrate preparation unit; and

transferring the exposed Nth substrate (513) by means of the robot from the second substrate preparation unit for removal from the lithography system unit;

wherein the clamped N+1th substrate is transferred (507) to the load lock unit before the exposed clamped Nth substrate is transferred (508) from the load lock unit.

6. The method of any one of the preceding claims, wherein the lithography system unit further comprises a substrate storage unit (410),

wherein the method further comprises transferring the Nth substrate (501) by means of the robot to the substrate storage unit, and

wherein transferring the Nth substrate (505) to a first one of the substrate preparation units comprises transferring the Nth substrate (505) by means of the robot from the substrate storage unit to a first one of the substrate preparation units.

7. The method of claim 6, wherein the lithography system unit further comprises a substrate interface unit (640), the interface unit arranged for transfer of the substrates between a substrate delivery robot and the substrate handling robot, and

wherein transferring the Nth substrate (501) to the substrate storage unit comprises transferring the Nth substrate (501) by means of the robot from the interface unit to the substrate storage unit, and

wherein transferring the exposed Nth substrate (513) for removal from the lithography system unit comprises transferring the exposed Nth substrate (513) by means of the robot from the second substrate preparation unit to the interface unit for removal from the lithography system unit.

8. The method of claim 7, wherein the lithography system further comprises a horizontal transfer robot arranged for receiving the substrates and transferring them horizontally to the interface unit, and for transferring exposed substrates from the interface unit and transferring them horizontally for removal from the lithography system unit, the method further comprising:

transferring the Nth substrate to the interface unit by means of the horizontal transfer robot prior to transferring the Nth substrate (501) to the substrate storage unit; and

transferring the exposed Nth substrate from the interface unit by means of the horizontal transfer robot after transferring the exposed Nth substrate to the interface unit by the substrate handling robot.

9. The method of any one of the preceding claims, wherein the first and second substrate preparation units and the first and second substrate positions of the load lock unit are arranged vertically with respect to each other, and wherein the substrate handling robot is arranged for transferring the substrates vertically between the substrate preparation units and the first and second substrate positions of the load lock unit, and the wherein the transferring steps of the method comprise vertical transfers by the substrate handling robot.

10. The method of any one of the preceding claims, wherein the lithography system unit further comprises a substrate storage unit and an interface unit, and wherein the first and second substrate preparation units, the first and second substrate positions of the load lock unit, the storage system, and the interface unit are arranged vertically with respect to each other, and wherein the substrate handling robot is arranged for transferring the substrates vertically between the substrate preparation units, the first and second substrate positions of the load lock unit, the storage system, and the interface unit.

11. The method of any one of the preceding claims, further comprising:

transferring the exposed clamped N-1th substrate (518) that was previously clamped to a third substrate support structure and exposed in the lithography apparatus, by means of the robot, from a different one of the first and second positions of the load lock than occupied by the clamped Nth substrate, to the first substrate preparation unit;

separating the exposed N-1th substrate from the third substrate support structure in the first substrate preparation unit; and transferring the exposed N-1th substrate (503) by means of the robot from the first substrate preparation unit for removal from the lithography system unit;

wherein the clamped Nth substrate is transferred (517) to the load lock unit before the exposure of the clamped N-1th substrate in the lithography apparatus is completed.

12. The method of any one of the preceding claims, further comprising, prior to clamping each of the substrates on one of the substrate support structures, pre-aligning the substrate towards a predetermined orientation in one of the substrate preparation units.

13. The method of any one of the preceding claims, further comprising a coarse pre-alignment of each of the substrates towards a predetermined orientation before transfer to one of the substrate preparation units for clamping the substrate.

14. The method of any one of the preceding claims, further comprising, prior to clamping each of the substrates on one of the substrate support structures, thermal conditioning of the substrate support structure by removing heat energy from the substrate support structure.

15. The method of any one of the preceding claims, wherein the load lock comprises a load lock robot (720), the method further comprising:

pumping down the load lock unit after transfer of the clamped Nth substrate to an unoccupied one of the first and second positions of the load lock unit;

transferring the exposed clamped N-1th substrate, by means of the load lock robot arm, from the lithography system unit to an unoccupied one of the first and second positions of the pumped down load lock unit;

transferring the clamped Nth substrate, by means of the load lock robot, from the pumped down load lock into the lithography system unit; and

venting the load lock unit prior to transferring the exposed clamped N-1th substrate to the first substrate preparation unit.

16. The method of any one of the preceding claims, wherein the first and second positions of the pumped down load lock unit are arranged vertically with respect to each other and the load lock robot (720) comprises an upper handling body (701a) arranged for transferring substrates from and to the first position and a lower handling body (701b) arranged for transferring substrates from and to the second position.

AMENDED CLAIMS
received by the International Bureau on 1 October 2012 (01.10.2012)

1. A method of processing substrates (405) in a lithography system unit (301) of a lithography system (300), the lithography system unit comprising at least two substrate preparation units (360) for preparing substrates, said preparing including clamping a substrate onto a substrate support structure, a load lock unit (310) comprising at least first and second substrate positions, and a substrate handling robot (401) for transferring substrates clamped onto substrate support structures between the substrate preparation units and the load lock unit, and for transferring unclamped substrates towards and from the substrate preparation units, wherein the method comprises:

providing a sequence of substrates (405) to be exposed to the robot, including an Nth substrate, an N-1th substrate immediately preceding the Nth substrate, and an N+1th substrate immediately following the Nth substrate;

transferring the Nth substrate (505) by means of the robot to a first one of the substrate preparation units;

clamping the Nth substrate on a first substrate support structure (403) in the first substrate preparation unit, the Nth substrate and first substrate support structure together forming a clamped Nth substrate;

transferring the clamped Nth substrate (517) by means of the robot from the first substrate preparation unit to an unoccupied one of the first and second positions in the load lock unit for exposure in the lithography system unit; and

exposing the clamped Nth substrate in the lithography system unit.

2. The method of claim 1, wherein the clamped Nth substrate is transferred (517) to the load lock unit before exposure of the N-1th substrate in the lithography system unit is completed.

3. The method of claim 1 or 2, further comprising:

transferring the N+1th substrate (515) by means of the robot to a second one of the substrate preparation units;

clamping the N+1th substrate on a second substrate support structure in the second substrate preparation unit, the N+1th substrate and second substrate support structure together forming a clamped N+1th substrate; and transferring the clamped N+1th substrate (507) by means of the robot from the second substrate preparation unit to an unoccupied one of the first and second positions in the load lock unit for exposure in the lithography apparatus.

4. The method of claim 3, wherein the clamped N+1th substrate is transferred (507) to the load lock unit before exposure of the Nth substrate in the lithography system unit is completed.

5. The method of any one of the preceding claims, further comprising:

transferring the exposed clamped Nth substrate (508), by means of the robot, from a different one of the first and second positions of the load lock than occupied by the clamped N+1th substrate, to the second substrate preparation unit;

separating the exposed Nth substrate from the first substrate support structure in the second substrate preparation unit; and

transferring the exposed Nth substrate (513) by means of the robot from the second substrate preparation unit for removal from the lithography system unit;

wherein the clamped N+1th substrate is transferred (507) to the load lock unit before the exposed clamped Nth substrate is transferred (508) from the load lock unit.

6. The method of any one of the preceding claims, wherein the lithography system unit further comprises a substrate storage unit (410),

wherein the method further comprises transferring the Nth substrate (501) by means of the robot to the substrate storage unit, and

wherein transferring the Nth substrate (505) to a first one of the substrate preparation units comprises transferring the Nth substrate (505) by means of the robot from the substrate storage unit to a first one of the substrate preparation units.

7. The method of claim 6, wherein the lithography system unit further comprises a substrate interface unit (640), the interface unit arranged for transfer of the substrates between a substrate delivery robot and the substrate handling robot, and

wherein transferring the Nth substrate (501) to the substrate storage unit comprises transferring the Nth substrate (501) by means of the robot from the interface unit to the substrate storage unit, and wherein transferring the exposed Nth substrate (513) for removal from the lithography system unit comprises transferring the exposed Nth substrate (513) by means of the robot from the second substrate preparation unit to the interface unit for removal from the lithography system unit.

8. The method of claim 7, wherein the lithography system further comprises a horizontal transfer robot arranged for receiving the substrates and transferring them horizontally to the interface unit, and for transferring exposed substrates from the interface unit and transferring them horizontally for removal from the lithography system unit, the method further comprising:

transferring the Nth substrate to the interface unit by means of the horizontal transfer robot prior to transferring the Nth substrate (501) to the substrate storage unit; and

transferring the exposed Nth substrate from the interface unit by means of the horizontal transfer robot after transferring the exposed Nth substrate to the interface unit by the substrate handling robot.

9. The method of any one of the preceding claims, wherein the first and second substrate preparation units and the first and second substrate positions of the load lock unit are arranged vertically with respect to each other, and wherein the substrate handling robot is arranged for transferring the substrates vertically between the substrate preparation units and the first and second substrate positions of the load lock unit, and the wherein the transferring steps of the method comprise vertical transfers by the substrate handling robot.

10. The method of any one of the preceding claims, wherein the lithography system unit further comprises a substrate storage unit and an interface unit, and wherein the first and second substrate preparation units, the first and second substrate positions of the load lock unit, the storage system, and the interface unit are arranged vertically with respect to each other, and wherein the substrate handling robot is arranged for transferring the substrates vertically between the substrate preparation units, the first and second substrate positions of the load lock unit, the storage system, and the interface unit.

11. The method of any one of the preceding claims, further comprising:

transferring the exposed clamped N-1th substrate (518) that was previously clamped to a third substrate support structure and exposed in the lithography apparatus, by means of the robot, from a different one of the first and second positions of the load lock than occupied by the clamped Nth substrate, to the first substrate preparation unit;

separating the exposed N-1th substrate from the third substrate support structure in the first substrate preparation unit; and

transferring the exposed N-1th substrate (503) by means of the robot from the first substrate preparation unit for removal from the lithography system unit;

wherein the clamped Nth substrate is transferred (517) to the load lock unit before the exposure of the clamped N-1th substrate in the lithography apparatus is completed.

12. The method of any one of the preceding claims, further comprising, prior to clamping each of the substrates on one of the substrate support structures, pre-aligning the substrate towards a predetermined orientation in one of the substrate preparation units.

13. The method of any one of the preceding claims, further comprising a coarse pre-alignment of each of the substrates towards a predetermined orientation before transfer to one of the substrate preparation units for clamping the substrate.

14. The method of any one of the preceding claims, further comprising, prior to clamping each of the substrates on one of the substrate support structures, thermal conditioning of the substrate support structure by removing heat energy from the substrate support structure.

15. The method of any one of the preceding claims, wherein the load lock comprises a load lock robot (720), the method further comprising:

pumping down the load lock unit after transfer of the clamped Nth substrate to an unoccupied one of the first and second positions of the load lock unit;

transferring the exposed clamped N-1th substrate, by means of the load lock robot arm, from the lithography system unit to an unoccupied one of the first and second positions of the pumped down load lock unit;

transferring the clamped Nth substrate, by means of the load lock robot, from the pumped down load lock into the lithography system unit; and

venting the load lock unit prior to transferring the exposed clamped N-1th substrate to the first substrate preparation unit.

16. The method of any one of the preceding claims, wherein the first and second positions of the pumped down load lock unit are arranged vertically with respect to each other and the load lock robot (720) comprises an upper handling body (701a) arranged for transferring substrates from and to the first position and a lower handling body (701b) arranged for transferring substrates from and to the second position.

STATEMENT UNDER ARTICLE 19 (1)

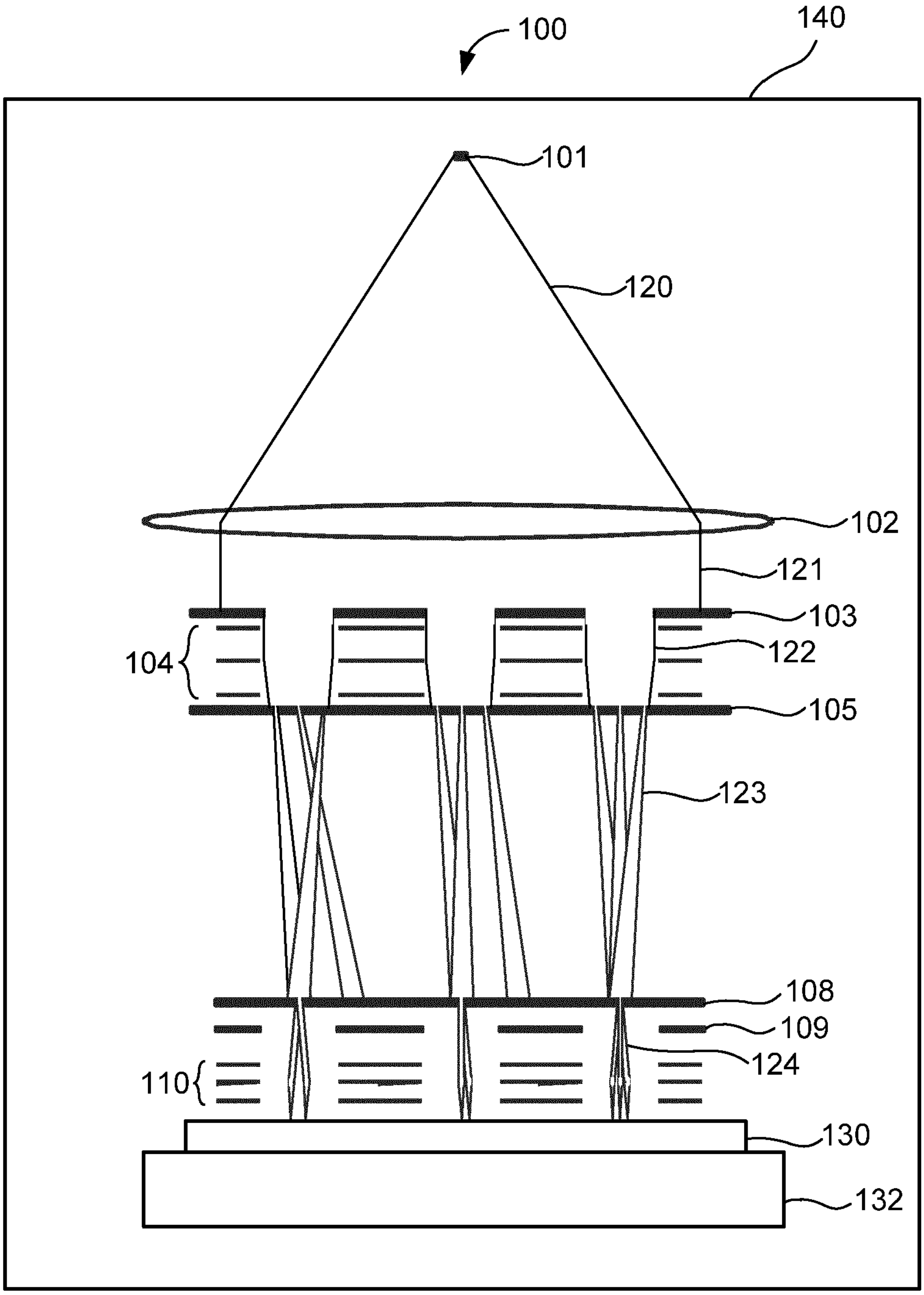
The present invention relates to a method of processing substrates in a lithography system unit. The lithography system unit comprises at least two substrate preparation units (360) for preparing substrates, a load lock unit (310), and a substrate handling robot (401). Preparing substrates in the preparation units includes clamping a substrate onto a substrate support structure. The load lock unit comprises at least first and second substrate positions. The substrate handling robot is arranged for transferring substrates clamped onto substrate support structures between the substrate preparation units and the load lock unit, and for transferring unclamped substrates towards and from the substrate preparation units.

The method includes providing a sequence of substrates to be exposed to the robot, including an Nth substrate, an N-1th substrate immediately preceding the Nth substrate, and an N+1 substrate immediately following the Nth substrate. The Nth substrate is subsequently transferred by means of the robot to a first one of the substrate preparation units, clamped on a first substrate support structure in the first substrate preparation unit so as to form a clamped Nth substrate, transferred, while being clamped, by means of the robot from the first substrate preparation unit to an unoccupied one of the first and second position in the load lock unit, and exposed in the lithography system unit.

International patent application WO 2010/094802 (D1) describes a charged particle lithography system comprising a single preparation unit (112) comprising a housing. The preparation unit is arranged for clamping an unclamped substrate onto a substrate support structure so as to form a clamped substrate. The unclamped substrate is provided via a first load port (131) into the housing of the preparation unit. After clamping, the clamped substrate is transferred out of the housing via a second load port (132). The clamped substrate is then provided to a lithography apparatus (113) for exposure via a load lock chamber (114) that is capable of handling a single clamped substrate. The load lock chamber thus has a single substrate position available.

D1 does not disclose a method of processing substrates in a lithography system comprising at least two substrate preparation units that may clamp a substrate onto a substrate support structure so as to form a clamped substrate, and a load lock unit comprising at least first and second substrate positions. Furthermore, D1 does not disclose the use of a substrate handling robot that is arranged for handling both unclamped substrates and clamped substrates.

The claimed method enables an efficient delivery of substrates to be exposed to a lithography system unit and retrieval of exposed substrates from such lithography system unit. In particular if such lithography system unit is part of a lithography system comprising multiple lithography system units, the method allows for maximizing the throughput of the lithography system as a whole. Furthermore, the method enables the use of a single substrate handling robot for transferring both clamped and unclamped substrates, which may reduce the size of the lithography system unit.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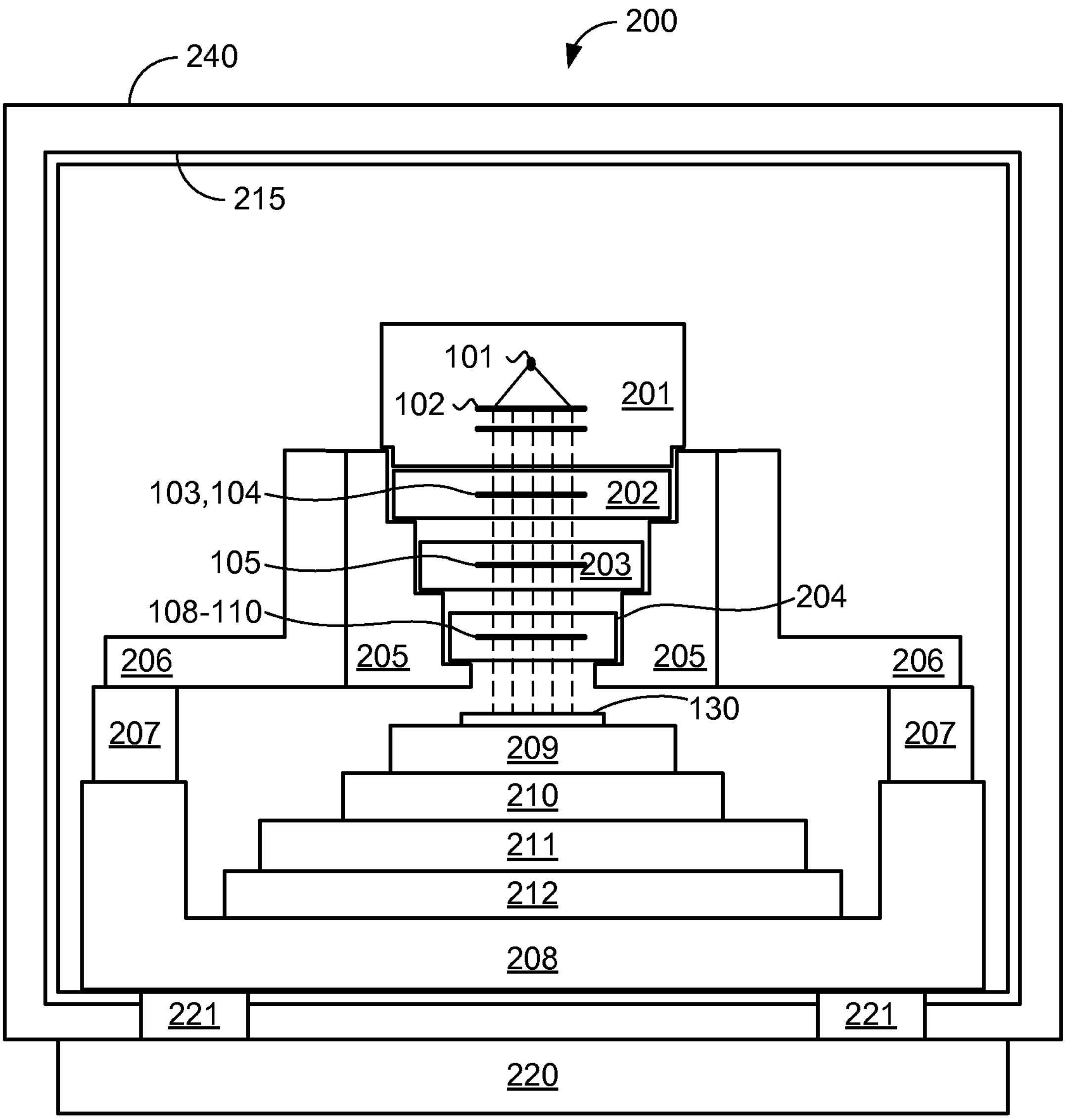
132

FIG. 1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221
220

FIG. 2

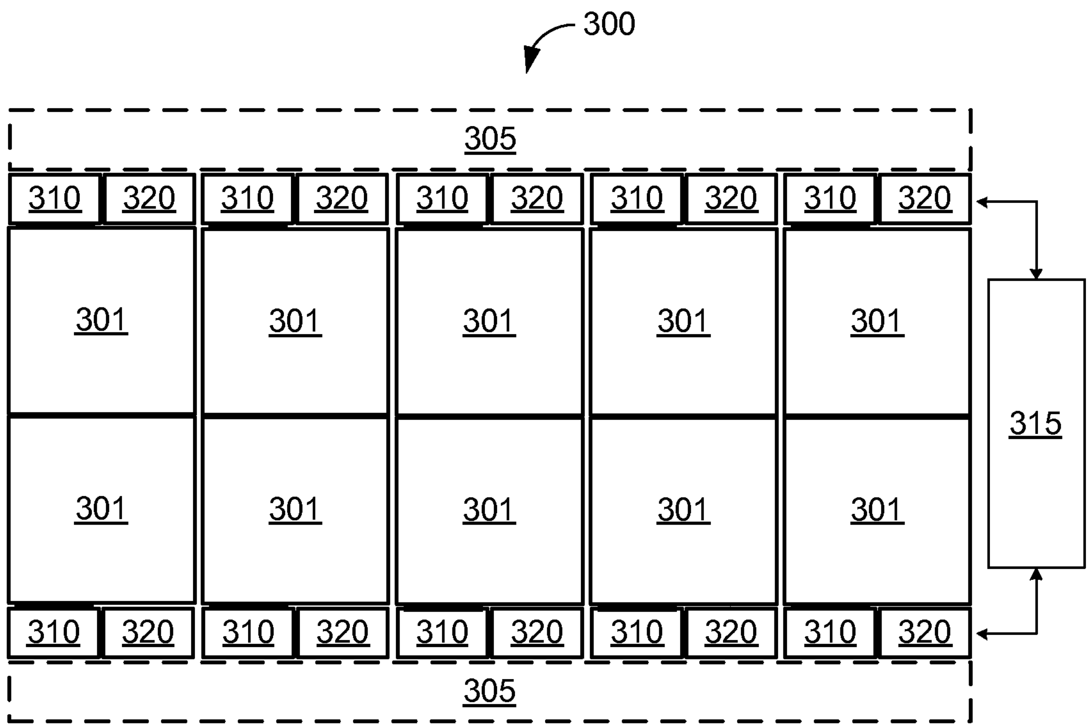


FIG. 3a

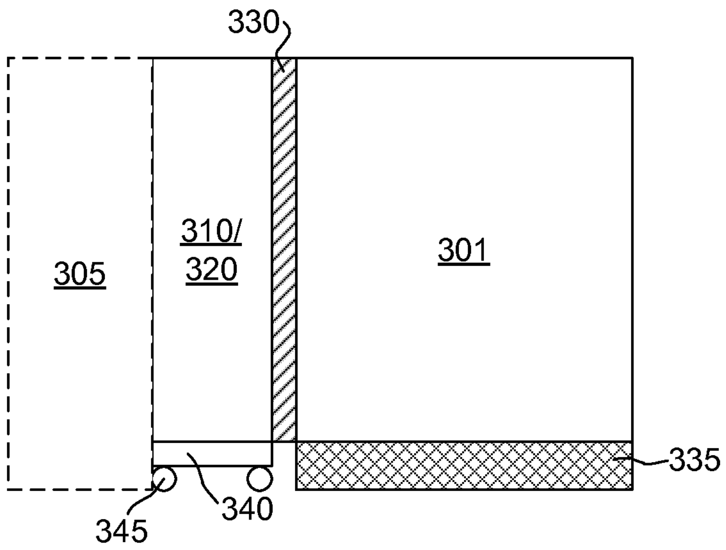


FIG. 3b

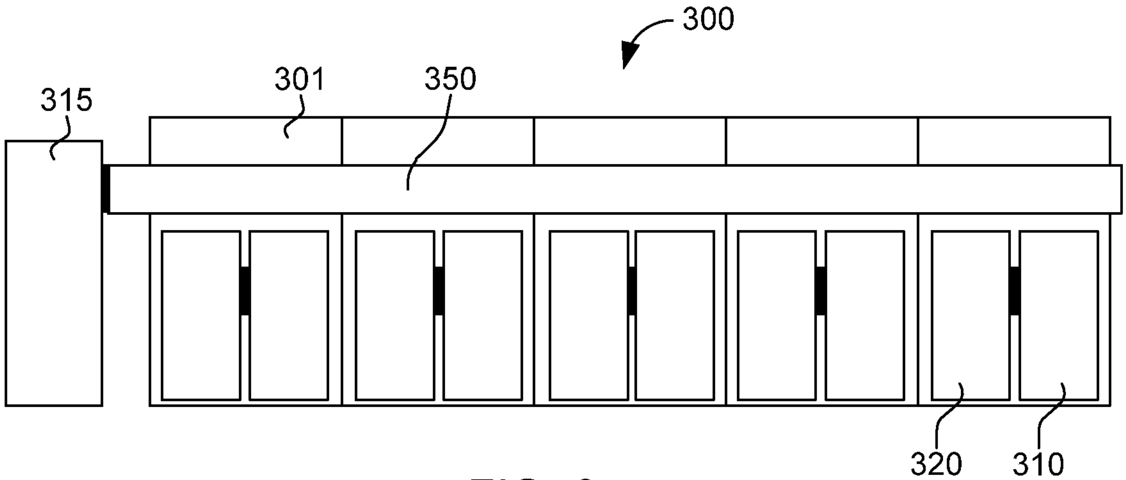
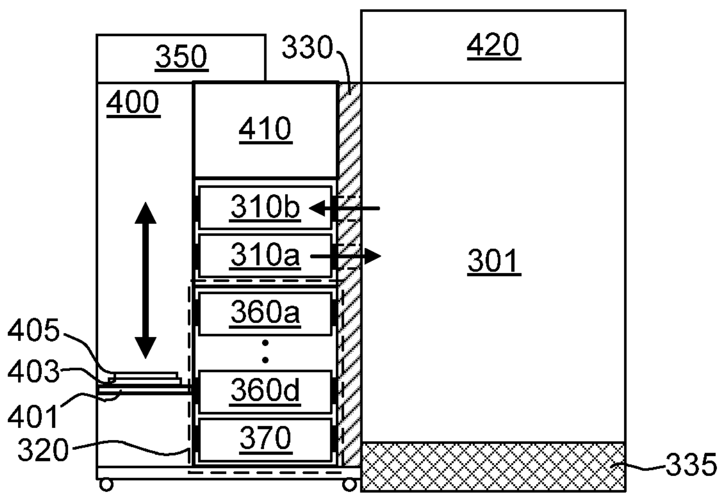

300
315
301
350
320
310

FIG. 3c

FIG. 4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310a
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360a
360d
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401
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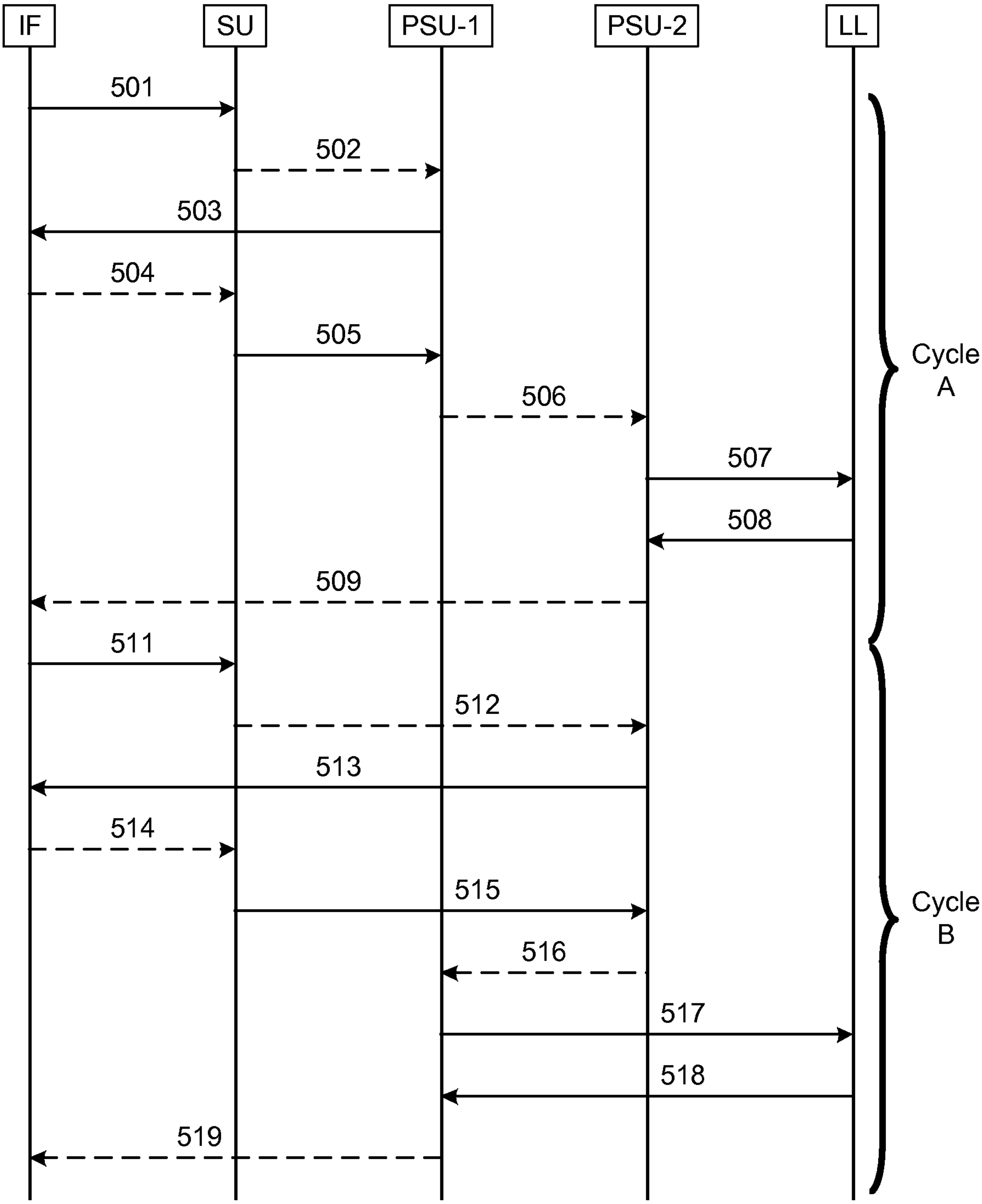
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PSU-1
PSU-2
LL
501
502
503
504
505
506
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508
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511
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513
514
515
516
517
518
519
Cycle A
Cycle B

FIG 5

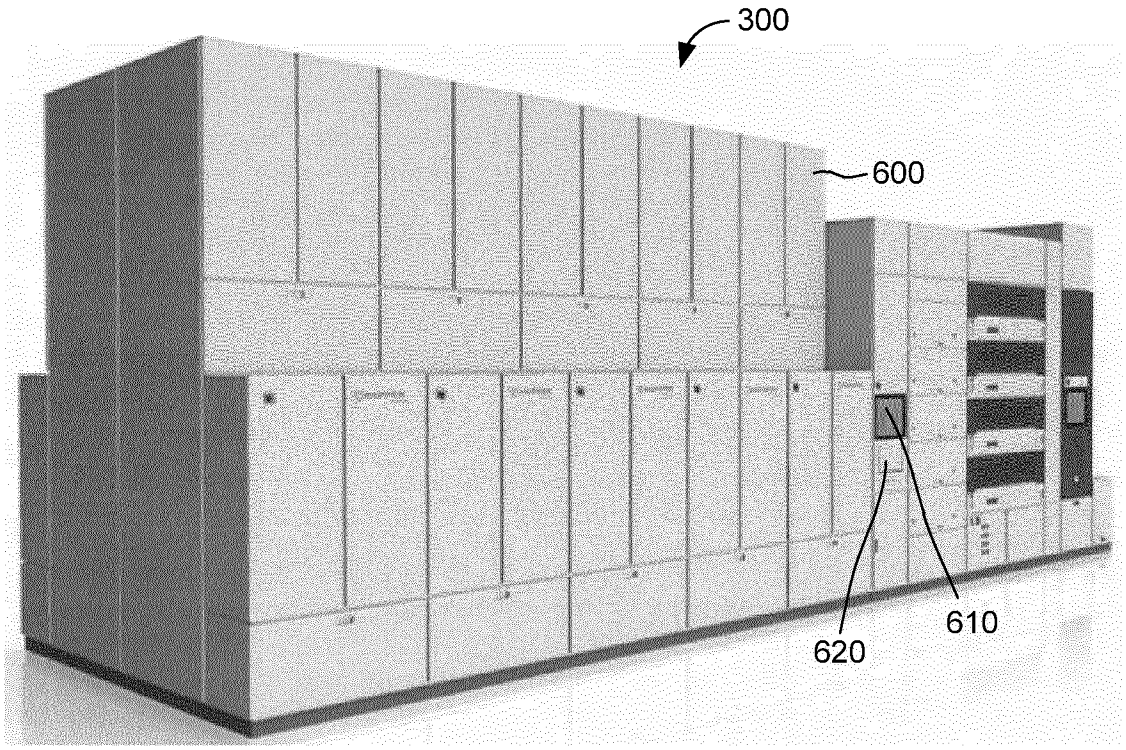

FIG. 6

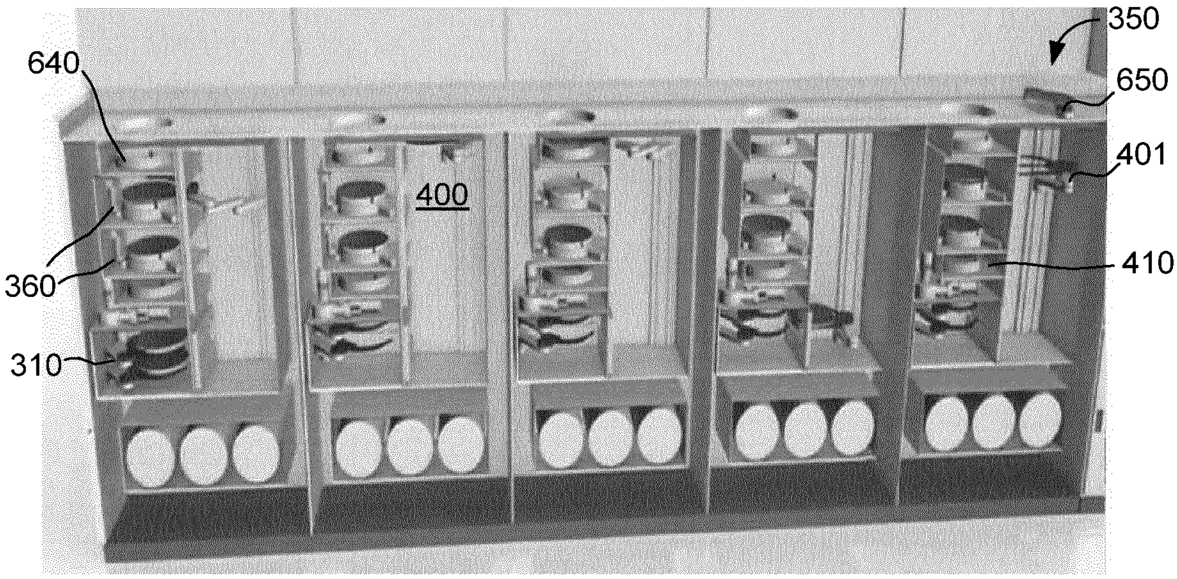

FIG. 7

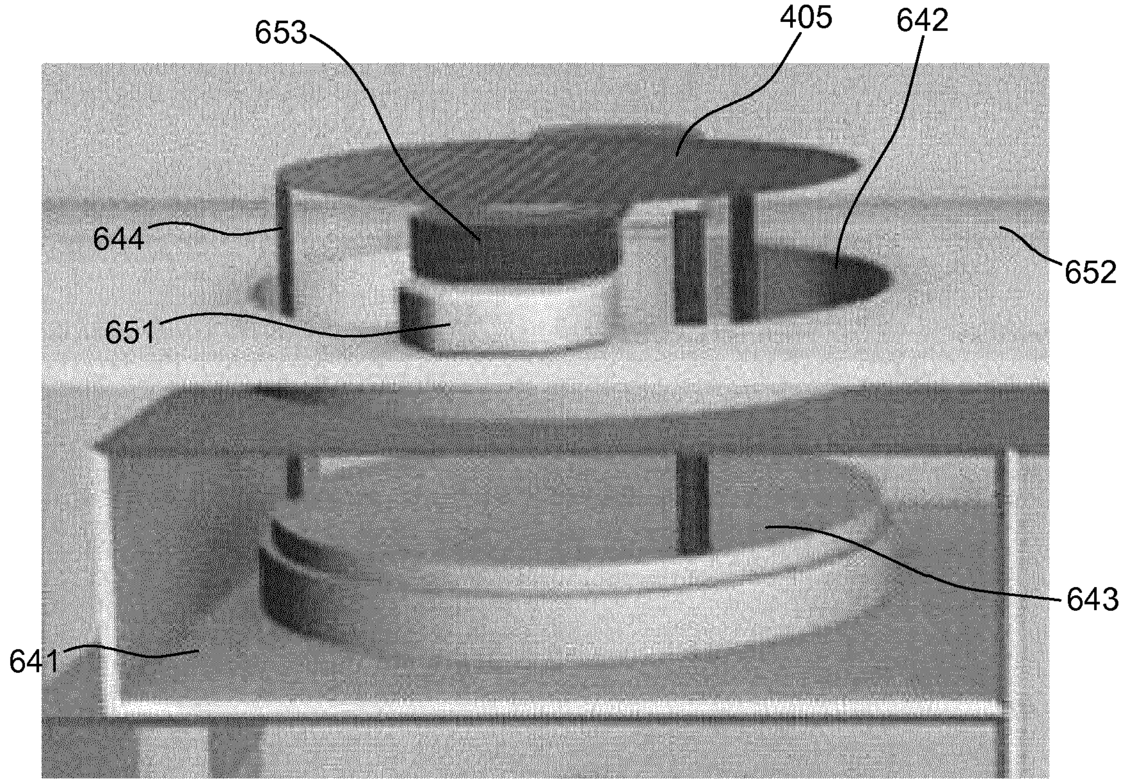

FIG. 8a

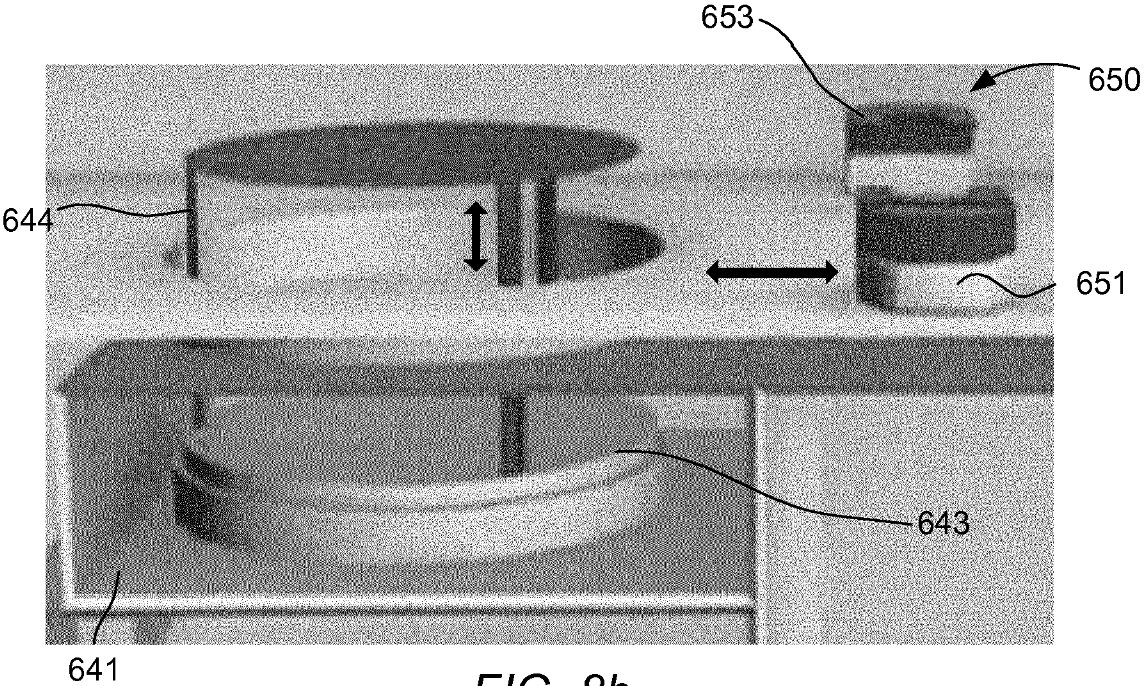

FIG. 8b

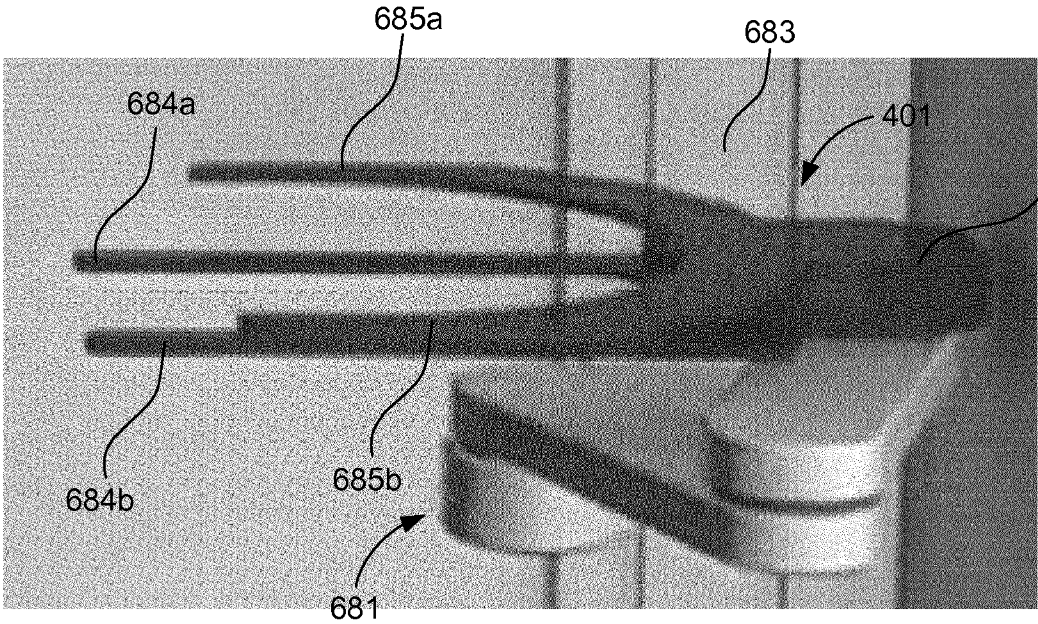

FIG. 9a

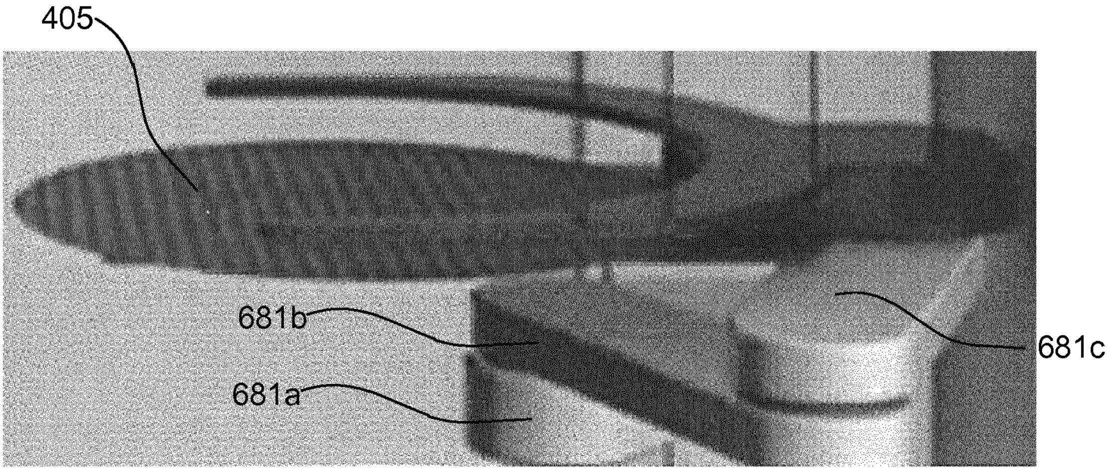

FIG. 9b

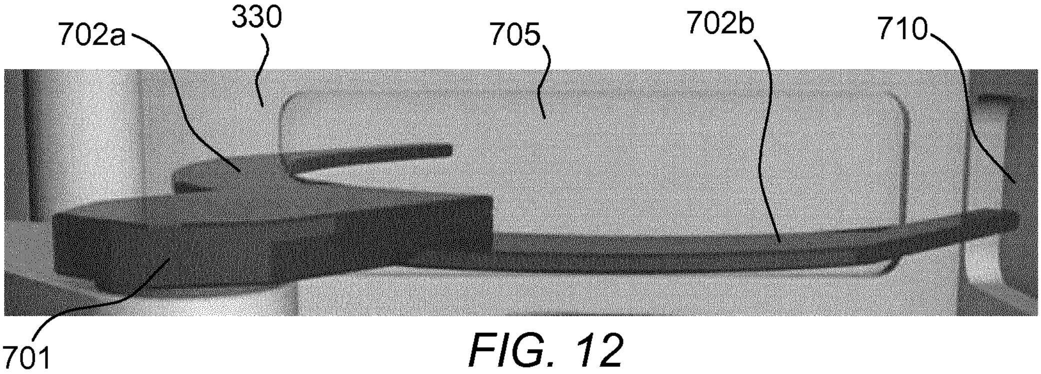

FIG. 12

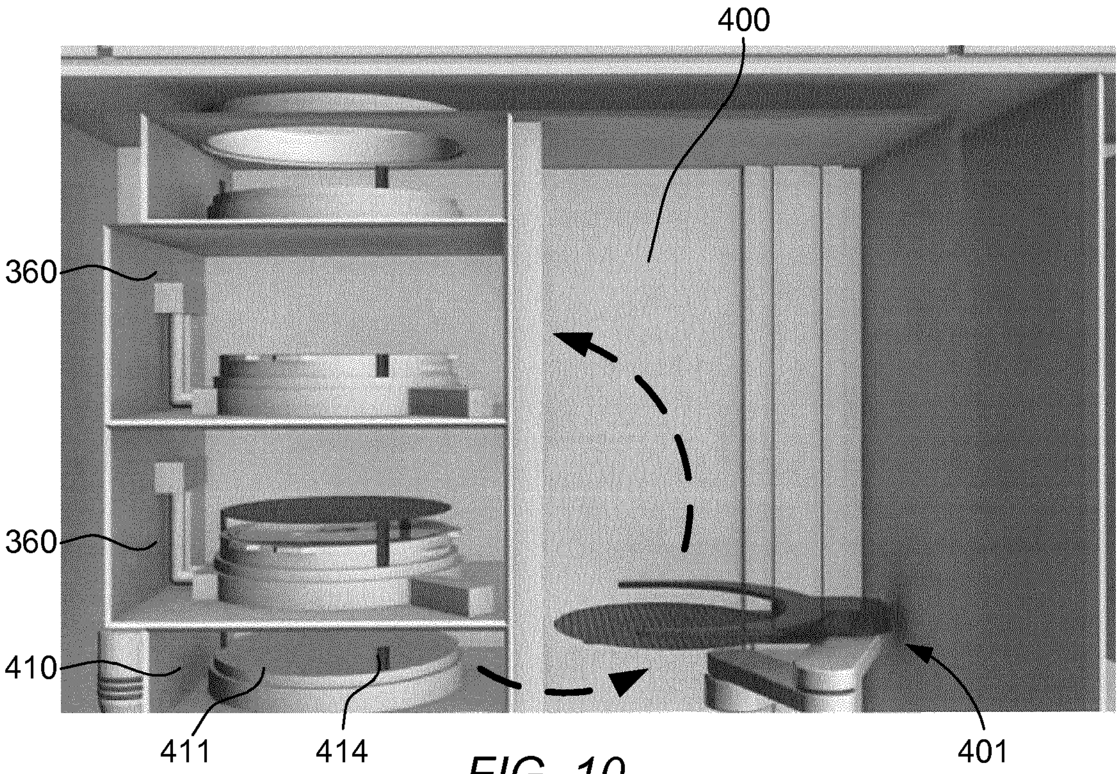

FIG. 10

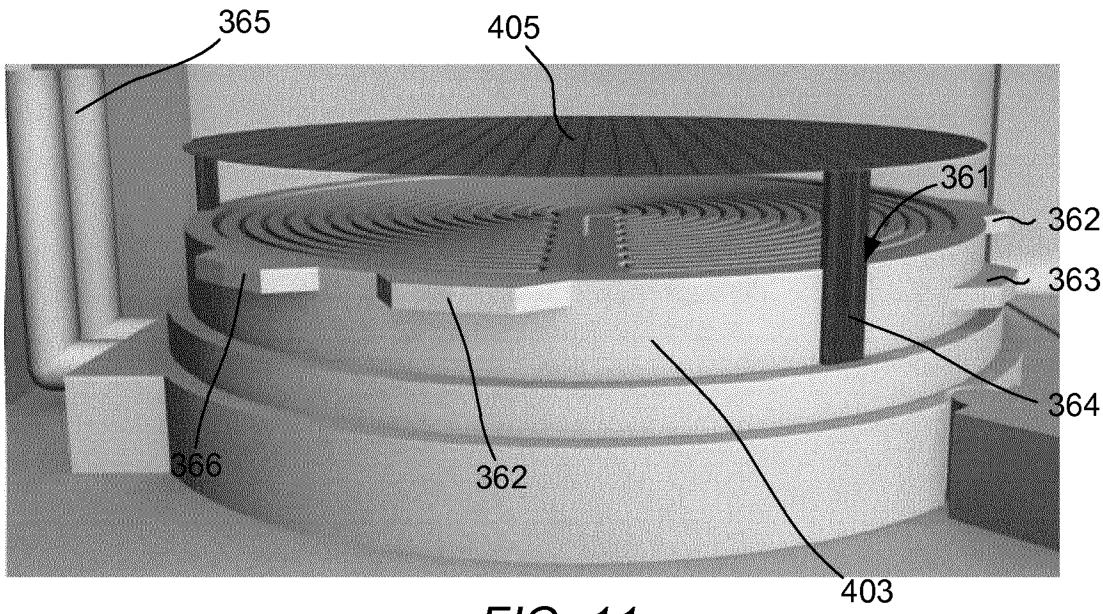

FIG. 11

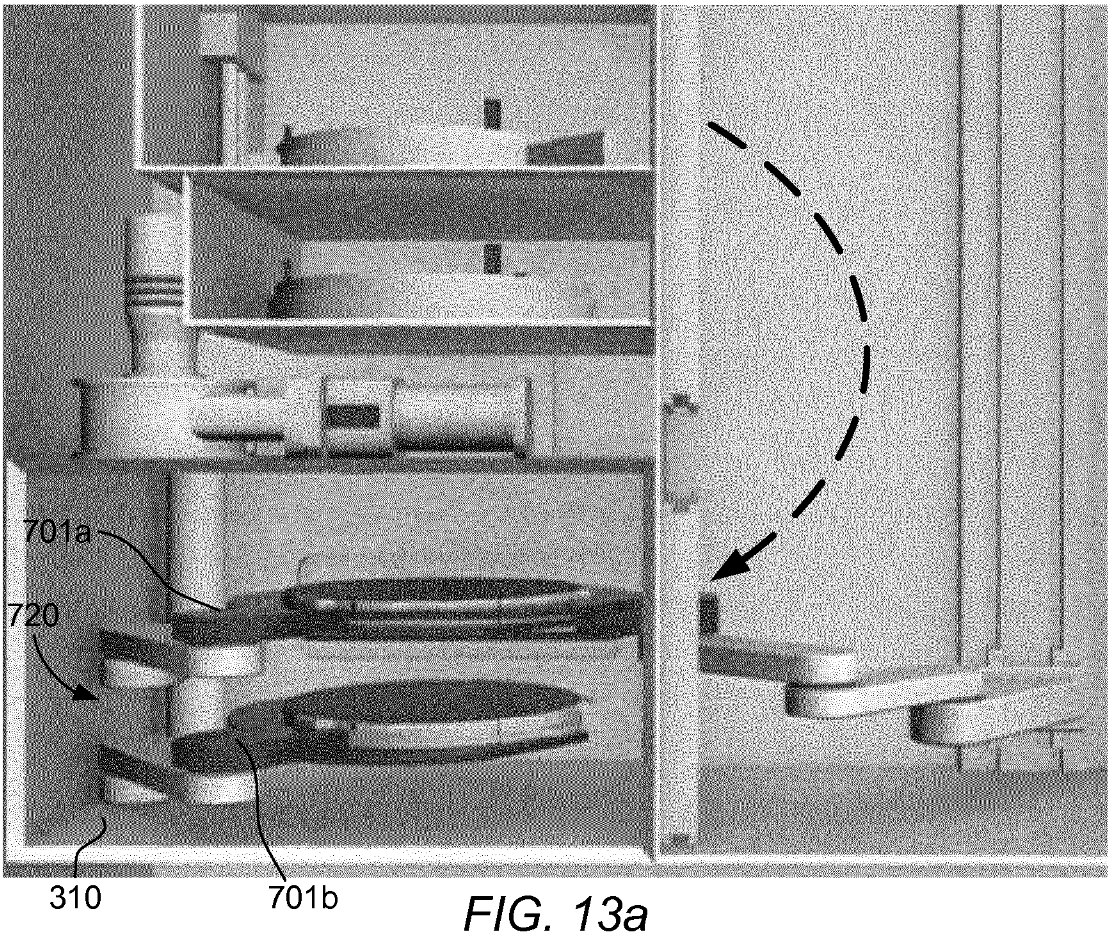

FIG. 13a

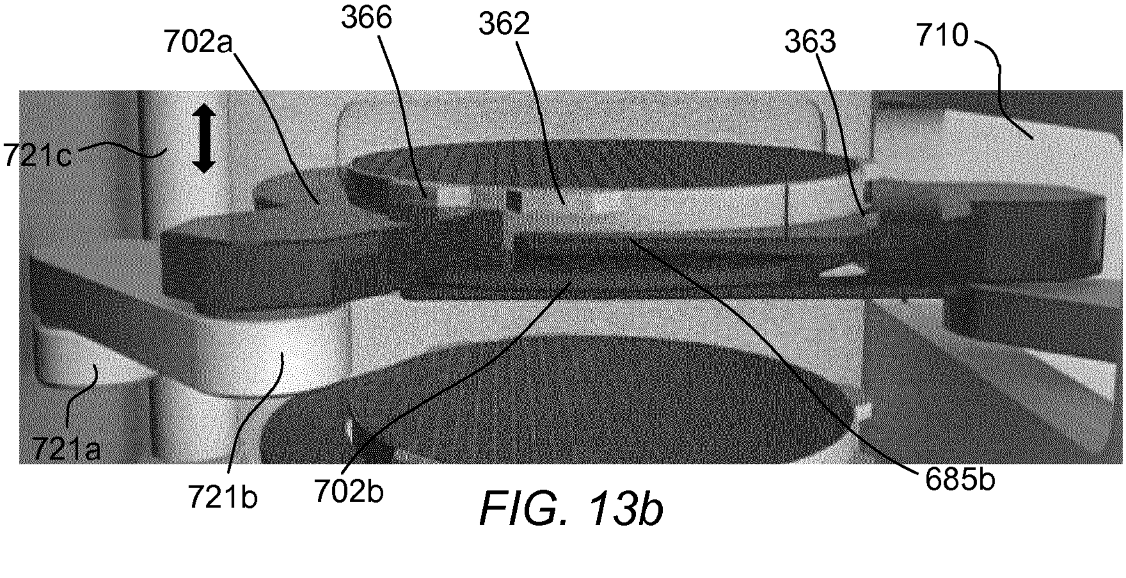

FIG. 13b

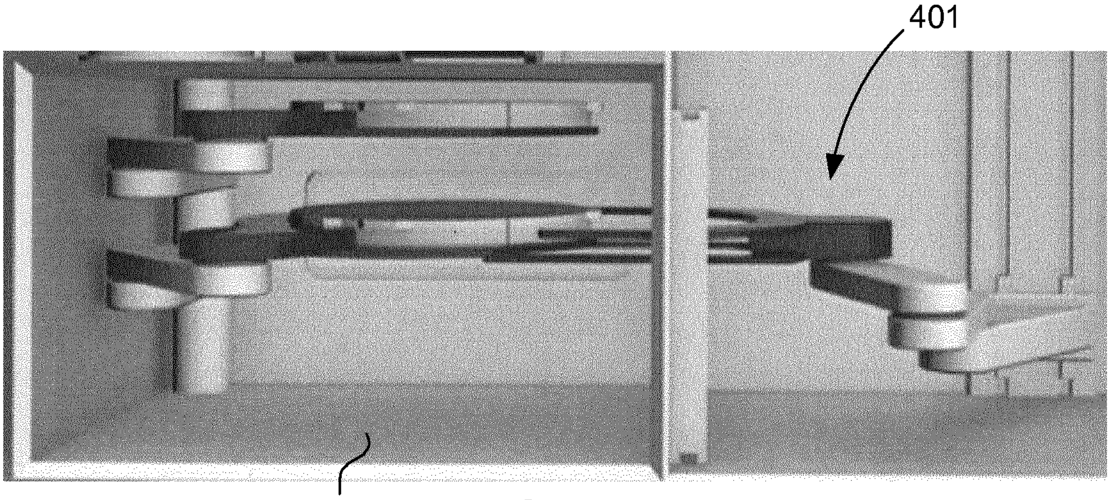

FIG. 14a

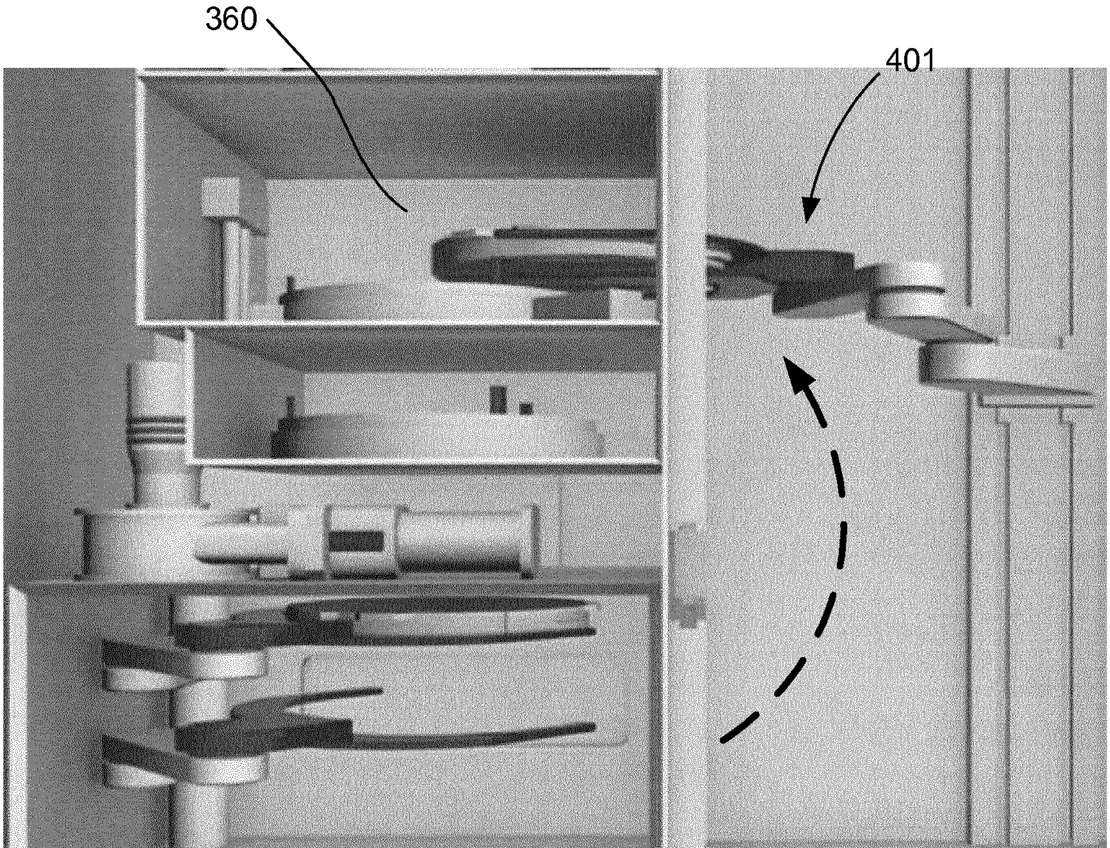

FIG. 14b

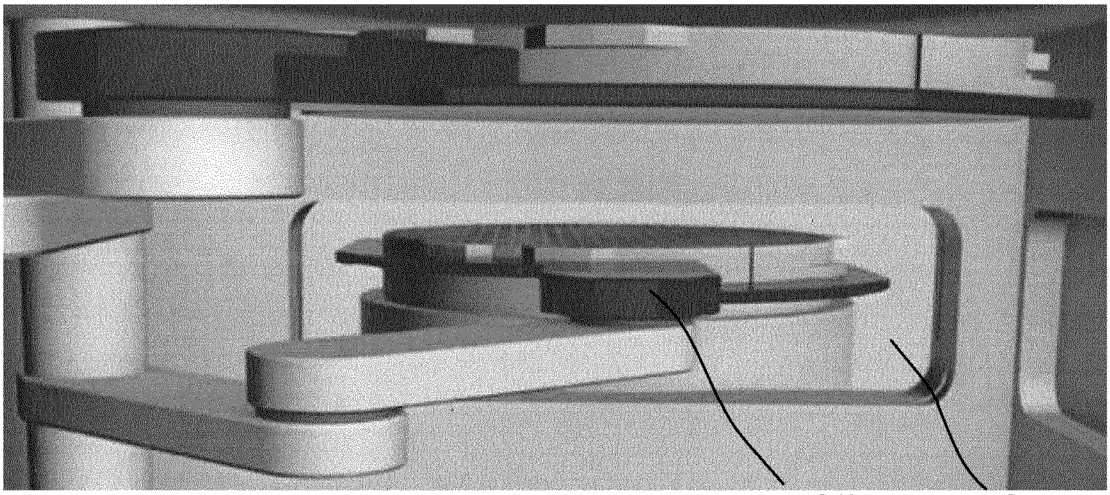

FIG. 15a

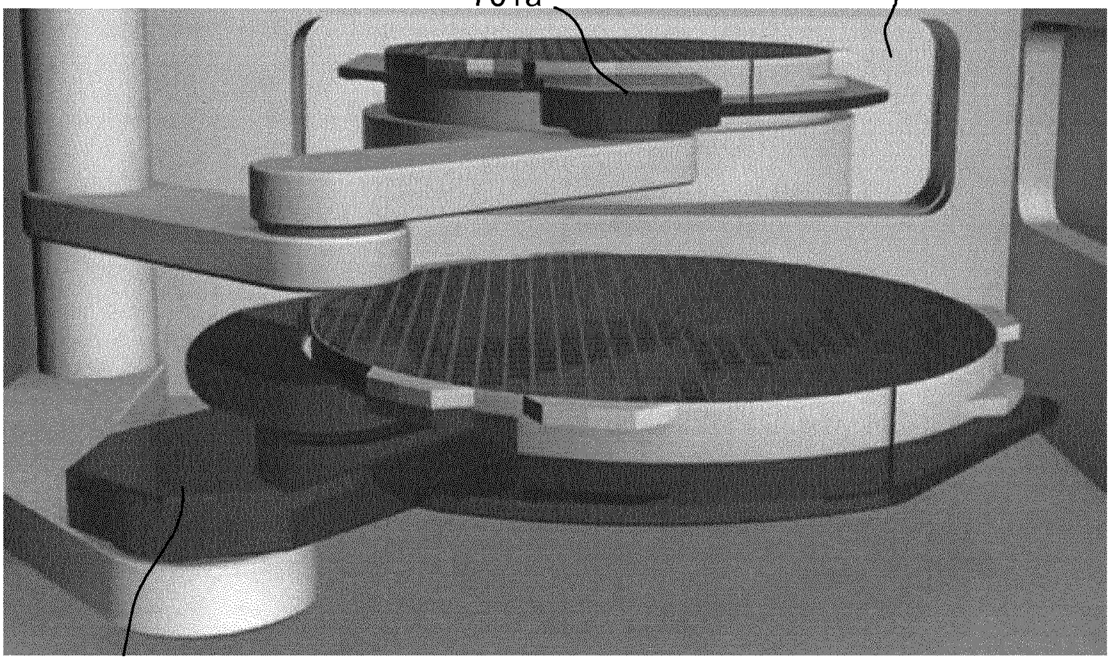

FIG. 15b

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2012/057955

A. CLASSIFICATION OF SUBJECT MATTER
INV. G03F7/20
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01L G03F

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2010/094802 A1 (MAPPER LITHOGRAPHY IP BV [NL]; DE JONG HENDRIK JAN [NL]) 26 August 2010 (2010-08-26) abstract figures 10,11 paragraphs [0001], [0089] - [0094] -----	1-16
A	EP 1 457 829 A1 (ASML NETHERLANDS BV [NL]) 15 September 2004 (2004-09-15) abstract figures 2,3 paragraphs [0001], [0014] -----	1

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 July 2012	01/08/2012

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

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2012/057955

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2010094802 A1	26-08-2010	CN 102414782 A EP 2399280 A1 TW 201106107 A US 2010238421 A1 WO 2010094802 A1	11-04-2012 28-12-2011 16-02-2011 23-09-2010 26-08-2010
EP 1457829 A1	15-09-2004	NONE	