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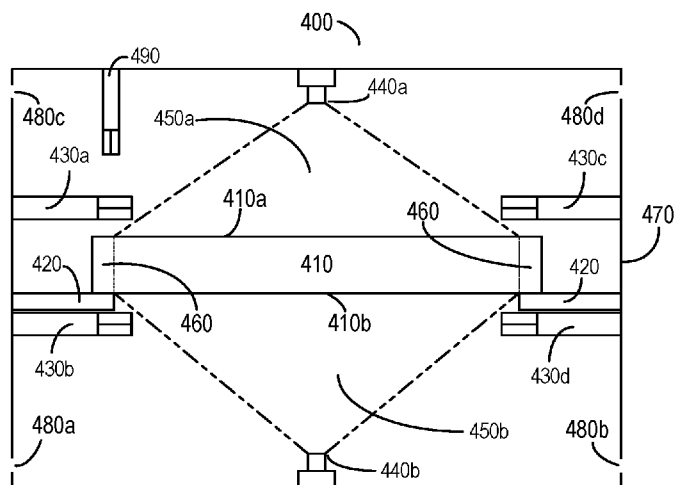


Fig. 4

(57) Abstract: Disclosed is a surface treatment apparatus and method for surface treatment of substrates such as wafers or substrates. The surface treatment apparatus comprises one or more support structures for supporting one or more substrates and one or more ultraviolet illumination sources configured to emit ultraviolet illumination, and being operable to treat said at least one surface of said one or more substrates while said one or more substrates being supported by said one or more support structures. The one or more ultraviolet illumination sources are distinct from an exposure source and not operable to emit exposure illumination for exposing a pattern on a wafer.

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SURFACE TREATMENT APPARATUS AND METHOD FOR SURFACE TREATMENT OF
PATTERNING DEVICES AND OTHER SUBSTRATES

CROSS-REFERENCE TO RELATED APPLICATIONS

- 5 **[0001]** This application claims priority of EP application 19183607.1 which was filed on July 1, 2019 and which is incorporated herein in its entirety by reference.

FIELD

- 10 **[0001]** The present invention relates to a lithographic apparatus and a method of lithography.

BACKGROUND

- 15 **[0002]** A lithographic apparatus is a machine that applies a desired pattern onto a substrate, usually onto a target portion of the substrate. A lithographic apparatus can be used, for example, in the manufacture of integrated circuits (ICs). In that instance, a patterning device, which is alternatively referred to as a mask or a reticle, may be used to generate a circuit pattern to be formed on an individual layer of the IC. This pattern can be transferred onto a target portion (e.g. comprising part of, one, or several dies) on a substrate (e.g. a silicon wafer). Transfer of the pattern is typically via imaging onto a layer of radiation-sensitive material (resist) provided on the substrate. In general, a single substrate will contain a network of adjacent target portions that are successively patterned. Lithography is widely recognized as one of the key steps in the manufacture of ICs and other devices and/or structures.

- 20 **[0003]** In order to reduce the minimum printable size, imaging may be performed using radiation having a short wavelength. It has therefore been proposed to use an EUV radiation source providing EUV radiation within the range of 13-14 nm, for example. It has further been proposed that EUV radiation with a wavelength of less than 10 nm could be used, for example within the range of 5-10 nm such as 6.7 nm or 6.8 nm. Such radiation is termed extreme ultraviolet (EUV) radiation or soft x-ray radiation.

- 25 **[0004]** Overlay error indicates the discrepancy between the actual location of the reticle pattern imaged onto the wafer and the desired location. There is a threshold to this error beyond which the result of the imaging is not acceptable. The order of magnitude is nanometers (in EUV) and shrinking with each next generation of EUV scanners. The process involves putting a next patterned layer onto a previous patterned layer in a stack of tens of layers that together will constitute eventually the integrated electronic circuit. A lateral displacement of one layer with another one might give rise to these layers being not properly connected, making the circuit unacceptable for operational use.

- 30 **[0005]** International patent application publication WO 2018/041599 is incorporated herein by reference. The publication discloses an EUV lithographic apparatus with a projection system which is configured to project via a slit a radiation beam, patterned by means of a mask, onto an exposure area on a substrate held on a substrate table. The substrate table is a component at the substrate stage and is

in physical contact with the substrate and may be physically and functionally integrated with the electrostatic clamp that clamps the substrate to the substrate table. The electrostatic clamp has a cooling system to transport away heat generated at the clamp. The lithographic apparatus operates in a scanning mode, wherein the mask and the substrate are scanned synchronously during the projection. A radiation beam used to project a pattern onto a substrate delivers a substantial amount of heat to that substrate, which causes localized heating of the substrate. Localized expansion of the substrate caused by the heating reduces the accuracy with which a projected pattern overlies patterns already present on the substrate. To address this problem, the lithographic apparatus disclosed in WO 2018/041599 comprises a cooling device located between the projection system and the substrate. The cooling device provides localized cooling of the substrate in the vicinity of the area where the patterned radiation beam is incident on the substrate via the slit.

[0006] The patterning devices or reticles should be completely dry before performing an exposure to avoid drift of the effective exposure dose.

SUMMARY

[0007] It would be desirable to improve on present patterning device treatment methods and apparatuses, particular for dehumidification of substrates such as patterning devices and/or wafers (substrates to be patterned).

[0008] In a first aspect of the invention, there is provided a surface treatment apparatus for surface treatment of substrates, comprising: one or more support structures for supporting one or more substrates; one or more ultraviolet illumination sources configured to emit ultraviolet illumination, and being operable to treat said at least one surface of said one or more substrates while said one or more substrates being supported by said one or more support structures; wherein said one or more ultraviolet illumination sources are distinct from an exposure source and not operable to emit exposure illumination for exposing a pattern on a wafer

[0009] In a second aspect of the invention, there is provided a lithographic apparatus comprising a surface treatment apparatus of the first aspect, for treating the surface of one or more substrates prior to performing an exposure.

[0010] In a third aspect of the invention, there is provided a method for treatment of at least one surface of one or more substrates used to pattern exposure illumination in a lithography process, said treatment comprising at least dehumidifying said at least one surface, the method comprising: illuminating the at least one surface with ultraviolet illumination, wherein said ultraviolet illumination is distinct from exposure illumination for exposing a pattern on a wafer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Embodiments of the invention will now be described, by way of example only, with reference to the accompanying schematic drawings in which corresponding reference symbols indicate corresponding parts, and in which:

[0012] Figure 1 depicts schematically a lithographic apparatus having reflective projection optics;

5 [0013] Figure 2 is a more detailed view of the apparatus of Figure 1 with a wafer-stage compartment;

[0014] Figure 3 illustrates schematically measurement and exposure processes in a dual-stage lithographic apparatus, according to known practice and modified in accordance with an embodiment of the present invention;

10 [0015] Figure 4 illustrates schematically an apparatus for surface treatment of patterning devices in a modular form, in accordance with a first embodiment of the present invention.

[0016] Figure 5 illustrates schematically another apparatus for surface treatment of patterning devices in a modular form, in accordance with a second embodiment of the present invention.

15 [0017] Figure 6 illustrates schematically an apparatus for surface treatment of patterning devices in an integrated form, in accordance with a third embodiment of the present invention.

DETAILED DESCRIPTION

[0018] Figure 1 schematically depicts a lithographic apparatus 100. The apparatus comprises:

[0019] - a source module SO;

20 [0020] - an illumination system (illuminator) IL configured to condition a radiation beam B (e.g. EUV radiation);

[0021] - a support structure (e.g. a mask stage) MT constructed to support a patterning device (e.g. a mask or a reticle) MA and connected to a first positioner PM configured to accurately position the patterning device;

25 [0022] - a substrate stage (e.g. a wafer stage) WT constructed to hold a substrate (e.g. a resist coated wafer) W and connected to a second positioner PW configured to accurately position the substrate; and

[0023] - a projection system (e.g. a reflective projection system) PS configured to project a pattern imparted to the radiation beam B by patterning device MA onto a target portion C (e.g. comprising one or more dies) of the substrate W.

[0024] The illumination system may include various types of optical components, such as refractive, reflective, magnetic, electromagnetic, electrostatic or other types of optical components, or any combination thereof, for directing, shaping, or controlling radiation.

35 [0025] The support structure MT holds the patterning device MA in a manner that depends on the orientation of the patterning device, the design of the lithographic apparatus, and other conditions, such as for example whether or not the patterning device is held in a vacuum environment. The support structure can use mechanical, vacuum, electrostatic or other clamping techniques to hold the patterning

device. The support structure may include a frame or a table, for example, which may be fixed or movable as required. The support structure may ensure that the patterning device is at a desired position, for example with respect to the projection system.

[0026] The term “patterning device” should be broadly interpreted as referring to any device that can be used to impart a radiation beam with a pattern in its cross-section such as to create a pattern in a target portion of the substrate. The pattern imparted to the radiation beam may correspond to a particular functional layer in a device being created in the target portion, such as an integrated circuit.

[0027] The patterning device may be transmissive or reflective. Examples of patterning devices include masks, programmable mirror arrays, and programmable LCD panels. Masks are well known in lithography, and include mask types such as binary, alternating phase-shift, and attenuated phase-shift, as well as various hybrid mask types. An example of a programmable mirror array employs a matrix arrangement of small mirrors, each of which can be individually tilted so as to reflect an incoming radiation beam in different directions. The tilted mirrors impart a pattern in a radiation beam which is reflected by the mirror matrix.

[0028] The projection system, like the illumination system, may include various types of optical components, such as refractive, reflective, magnetic, electromagnetic, electrostatic or other types of optical components, or any combination thereof, as appropriate for the exposure radiation being used, or for other factors such as the use of a vacuum. It may be desired to use a vacuum for EUV radiation since other gases may absorb too much radiation. A vacuum environment may therefore be provided to the whole beam path with the aid of a vacuum wall and vacuum pumps.

[0029] As here depicted, the apparatus is of a reflective type (e.g. employing a reflective mask).

[0030] The lithographic apparatus may be of a type having two (dual stage) or more substrate stages (and/or two or more mask stages). In such “multiple stage” machines the additional stages may be used in parallel, or preparatory steps may be carried out on one or more stages while one or more other stages are being used for exposure.

[0031] Referring to Figure 1, the illuminator IL receives an extreme ultra violet radiation beam from the source module SO. Methods to produce EUV light include, but are not necessarily limited to, converting a material into a plasma state that has at least one element, e.g., xenon, lithium or tin, with one or more emission lines in the EUV range. In one such method, often termed laser produced plasma (“LPP”) the required plasma can be produced by irradiating a fuel, such as a droplet, stream or cluster of material having the required line-emitting element, with a laser beam. The source module SO may be part of an EUV radiation system including a laser, not shown in Figure 1, for providing the laser beam exciting the fuel. The resulting plasma emits output radiation, e.g., EUV radiation, which is collected using a radiation collector, disposed in the source module. The laser and the source module may be separate entities, for example when a CO₂ laser is used to provide the laser beam for fuel excitation.

[0032] In such cases, the laser is not considered to form part of the lithographic apparatus and the radiation beam is passed from the laser to the source module with the aid of a beam delivery system comprising, for example, suitable directing mirrors and/or a beam expander. In other cases the source may be an integral part of the source module, for example when the source is a discharge produced
5 plasma EUV generator, often termed as a DPP source.

[0033] The illuminator IL may comprise an adjuster for adjusting the angular intensity distribution of the radiation beam. Generally, at least the outer and/or inner radial extent (commonly referred to as σ -outer and σ -inner, respectively) of the intensity distribution in a pupil plane of the illuminator can be adjusted. In addition, the illuminator IL may comprise various other components, such as faceted field
10 and pupil mirror devices. The illuminator may be used to condition the radiation beam, to have a desired uniformity and intensity distribution in its cross section.

[0034] The radiation beam B is incident on the patterning device (e.g., mask) MA, which is held on the support structure (e.g., mask stage) MT, and is patterned by the patterning device. After being reflected from the patterning device (e.g. mask) MA, the radiation beam B passes through the projection
15 system PS, which focuses the beam onto a target portion C of the substrate W. With the aid of the second positioner PW and position sensor PS2 (e.g. an interferometric device, linear encoder or capacitive sensor), the substrate stage WT can be moved accurately, e.g. so as to position different target portions C in the path of the radiation beam B. Similarly, the first positioner PM and another position sensor PS1 can be used to accurately position the patterning device (e.g. mask) MA with respect to the
20 path of the radiation beam B. Patterning device (e.g. mask) MA and substrate W may be aligned using mask alignment marks M1, M2 and substrate alignment marks P1, P2.

[0035] An EUV membrane, for example a pellicle PE, is provided to prevent contamination of the patterning device from particles within the system. Such pellicles may be provided at the location shown and/or at other locations. A further EUV membrane SPF may be provided as a spectral purity filter,
25 operable to filter out unwanted radiation wavelengths (for example DUV). Such unwanted wavelengths can affect the photoresist on wafer W in an undesirable manner. The SPF may also optionally help prevent contamination of the projection optics within projection system PS from particles released during outgassing (or alternatively a pellicle may be provided in place of the SPF to do this). Either of these EUV membranes may comprise any of the EUV membranes disclosed herein.

[0036] The depicted apparatus could be used in a variety of modes. In a scan mode, the patterning device support (e.g., mask stage) MT and the substrate stage WT are scanned synchronously while a pattern imparted to the radiation beam is projected onto a target portion C (i.e., a single dynamic exposure). The speed and direction of the substrate stage WT relative to the patterning device support (e.g., mask stage) MT may be determined by the (de-)magnification and image reversal characteristics
30 of the projection system PS. In scan mode, the maximum size of the exposure field limits the width (in the non-scanning direction) of the target portion in a single dynamic exposure, whereas the length of the scanning motion determines the height (in the scanning direction) of the target portion. Other types

of lithographic apparatus and modes of operation are possible, as is well-known in the art. For example, a step mode is known. In so-called “maskless” lithography, a programmable patterning device is held stationary but with a changing pattern, and the substrate stage WT is moved or scanned.

[0037] Combinations and/or variations on the above described modes of use or entirely different modes of use may also be employed.

[0038] Figure 2 shows an embodiment of the lithographic apparatus in more detail, including a radiation system 42, the illumination system IL, the patterning device chamber PD and the projection system PS. The radiation system 42 as shown in Figure 2 is of the type that uses a laser-produced plasma as a radiation source. EUV radiation may be produced by a very hot plasma created from, for example, xenon (Xe), lithium (Li) or tin (Sn). In an embodiment, Sn is used to create the plasma in order to emit the radiation in the EUV range.

[0039] The radiation system 42 embodies the function of source SO in the apparatus of Figure 1. Radiation system 42 comprises a source chamber 47, in this embodiment not only substantially enclosing a source of EUV radiation, but also collector 50 which, in the example of Figure 2, is a normal-incidence collector, for instance a multi-layer mirror.

[0040] As part of an LPP radiation source, a laser system 61 is constructed and arranged to provide a laser beam 63 which is delivered by a beam delivering system 65 through an aperture 67 provided in the collector 50. Also, the radiation system includes a target material 69, such as Sn or Xe, which is supplied by target material supply 71. The beam delivering system 65, in this embodiment, is arranged to establish a beam path focused substantially upon a desired plasma formation position 73.

[0041] In operation, the target material 69, which may also be referred to as fuel, is supplied by the target material supply 71 in the form of droplets. A trap 72 is provided on the opposite side of the source chamber 47, to capture fuel that is not, for whatever reason, turned into plasma. When such a droplet of the target material 69 reaches the plasma formation position 73, the laser beam 63 impinges on the droplet and an EUV radiation-emitting plasma forms inside the source chamber 47. In the case of a pulsed laser, this involves timing the pulse of laser radiation to coincide with the passage of the droplet through the position 73. These create a highly ionized plasma with electron temperatures of several 105 K. The energetic radiation generated during de-excitation and recombination of these ions includes the wanted EUV which is emitted from the plasma at position 73. The plasma formation position 73 and the aperture 52 are located at first and second focal points of collector 50, respectively and the EUV radiation is focused by the normal-incidence collector mirror 50 onto the intermediate focus point IF.

[0042] The beam of radiation emanating from the source chamber 47 traverses the illumination system IL via reflectors 53, 54, as indicated in Figure 2 by the radiation beam 56. The reflectors direct the beam 56, via pellicle PE, onto a patterning device (e.g. reticle or mask) positioned on a support (e.g. reticle stage or mask stage) MT in the patterning device chamber PD. A patterned beam 57 is formed, which is imaged by projection system PS via reflective elements 58, 59 onto a substrate carried by wafer

stage or substrate stage WT. The substrate W is held on the substrate stage WT by an electrostatic clamp CL. The substrate stage WT with its camp CL is housed in a wafer-stage compartment WSC.

[0043] The projection system PS has projection optics mounted in a container (box) providing a specific low-pressure environment. This is known as a projection optics box (POB). The POB and the wafer-stage compartment WSC are separate environments. During exposure, the photoresist may be outgassing owing to the radiation received from the POB. These gasses should not reach the projection optics as they may contaminate the surfaces of the mirrors (the POB contains reflective optical components in EUV). Contamination may then interfere with the imaging. Therefore, a dynamic gas lock DGL (not shown) is provided to reduce such contamination.

[0044] More elements than shown may generally be present in illumination system IL and projection system PS. For example there may be one, two, three, four or even more reflective elements present, rather than the two elements 58 and 59 shown in Figure 2.

[0045] As the skilled person will know, reference axes X, Y and Z may be defined for measuring and describing the geometry and behavior of the apparatus, its various components, and the radiation beams 55, 56, 57. At each part of the apparatus, a local reference frame of X, Y and Z axes may be defined. The Z axis broadly coincides with the direction of optical axis O at a given point in the system, and is generally normal to the plane of a patterning device (reticle) MA when describing the spatial relationships with reference to the patterning device and normal to the plane of substrate W when describing the spatial relationships with reference to the substrate W. In the source module (apparatus) 42, the X axis coincides broadly with the direction of fuel stream (69, described below), while the Y axis is orthogonal to that, pointing out of the page as indicated. On the other hand, in the vicinity of the support structure MT that holds the reticle MA, the local X axis is generally transverse to a scanning direction aligned with the local Y axis. For convenience, in this area of the schematic diagram Figure 2, the X axis points out of the page, again as marked. These designations are conventional in the art and will be adopted herein for convenience. In principle, any reference frame can be chosen to describe the apparatus and its behavior.

[0046] In addition to the wanted EUV radiation, the plasma may produce other wavelengths of radiation, for example in the infrared, visible, UV (ultraviolet) and DUV (deep ultraviolet) ranges. There may also be IR (infrared) radiation present from the laser beam 63. The non-EUV wavelengths are not wanted in the illumination system IL and projection system PS and various measures may be deployed to block the non-EUV radiation. As schematically depicted in Figure 2, a spectral purity filter SPF may be applied upstream of the virtual source point IF, for IR, DUV and/or other unwanted wavelengths. In the specific example shown in Figure 2, two spectral purity filters are depicted, one within the source chamber 47 and one at the output of the projection system PS.

[0047] Figure 3 illustrates the steps to expose target portions (e.g. dies) on a substrate W in a dual stage lithographic apparatus. The two substrate stages (also known as wafer stages) are configured to follow a route within the wafer-stage compartment (WSC in Figure 2) in operational use of the

lithographic apparatus. The substrate starts in a pre-aligner and is transferred to a substrate stage that holds the substrate in the clamp. The substrate is then conveyed along a route indicated by the steps 200, 202, 204, 210, 212, 214, 216, 218, 210 and 220.

5 [0048] The vacuum pre-aligner VPA is part of the wafer handler. The pre-aligner is a robot that puts the substrate W' into the correct orientation (in the local X-Y plane) so that the substrate W' has the correct orientation when transferred to the substrate stage at step 200 and is ready for the measure operation MEA.

10 [0049] Within the left-hand dashed box are steps performed at a measurement station MEA, while the right-hand side dashed box shows steps performed at the exposure station EXP. From time to time, one of the substrate stages WTa, WTb will be at the exposure station, while the other is at the measurement station, as described above. At step 200, a new substrate W' is loaded from the vacuum pre-aligner VPA by a mechanism not shown. These two substrates are processed in parallel (one at the measurement station and another one at the expose station) in order to increase the throughput of the lithographic apparatus.

15 [0050] Referring initially to the newly-loaded substrate W', this may be a previously unprocessed substrate, prepared with a new photo resist for first time exposure in the apparatus. In general, however, the lithography process described will be merely one step in a series of exposure and processing steps, so that substrate W' has been through this apparatus and/or other lithography apparatuses, several times already, and may have subsequent processes to undergo as well. Particularly for the problem of
20 improving overlay performance, the task is to ensure that new patterns are applied in exactly the correct position on a substrate that has already been subjected to one or more cycles of patterning and processing. These processing steps progressively introduce distortions in the substrate that must be measured and corrected for, to achieve satisfactory overlay performance.

[0051] The previous and/or subsequent patterning step may be performed in other lithography
25 apparatuses, as just mentioned, and may even be performed in different types of lithography apparatus. For example, some layers in the device manufacturing process which are very demanding in parameters such as resolution and overlay may be performed in a more advanced lithography tool than other layers that are less demanding. Therefore, some layers may be exposed in an immersion type lithography tool, while others are exposed in a 'dry' tool or in a vacuum tool. Some layers may be exposed in a tool
30 working at DUV wavelengths, while others are exposed using EUV wavelength radiation.

[0052] At 202, alignment measurements using the substrate marks P1 (depicted as four crosses) etc. and image sensors (not shown) are used to measure and record alignment of the substrate relative to substrate stages WTa/WTb. In addition, several alignment marks across the substrate W' will be measured using alignment sensor AS. These measurements are used in one embodiment to establish a
35 "wafer grid", which maps very accurately the distribution of marks across the substrate, including any distortion relative to a nominal rectangular grid.

[0053] At step 204, a map of wafer height (Z) against X-Y position is measured also using the level sensor LS. Conventionally, the height map is used only to achieve accurate focusing of the exposed pattern. Primarily, the height map is used only to achieve accurate focusing of the exposed pattern. It may be used for other purposes in addition.

5 [0054] When substrate W' was loaded, recipe data 206 were received, defining the exposures to be performed, and also properties of the wafer and the patterns previously made and to be made upon it. To these recipe data are added the measurements of wafer position, wafer grid and height map that were made at 202, 204, so that a complete set of recipe data and measurement data 208 can be passed to the exposure station EXP. The measurements of alignment data for example comprise X and Y positions
10 of alignment targets formed in a fixed or nominally fixed relationship to the product patterns that are the product of the lithographic process. These alignment data, taken just before exposure, are used to generate an alignment model with parameters that fit the model to the data. These parameters and the alignment model will be used during the exposure operation to correct positions of patterns applied in the current lithographic step. The model in use interpolates positional deviations between the measured
15 positions. A conventional alignment model might comprise four, five or six parameters, together defining translation, rotation and scaling of the 'ideal' grid, in different dimensions. Advanced models are known that use more parameters.

[0055] At 210, wafers W' and W are swapped, so that the measured substrate W' becomes the substrate W entering the exposure station EXP. In the example apparatus of Figure 1, this swapping is
20 performed by exchanging the substrate stages WTa and WTb within the apparatus, so that the substrates W, W' remain accurately clamped and positioned on those supports, to preserve relative alignment between the substrate stages and substrates themselves. Accordingly, once the stages have been swapped, determining the relative position between projection system PS and substrate stage WTb (formerly WTa) is all that is necessary to make use of the measurement information 202, 204 for the
25 substrate W (formerly W') in control of the exposure steps. At step 212, reticle alignment is performed using mask alignment marks (not shown). In steps 214, 216, 218, scanning motions and radiation are applied at successive target locations across the substrate W, in order to complete the exposure of a number of patterns.

[0056] By using the alignment data and height map obtained at the measuring station in the
30 performance of the exposure steps, these patterns are accurately aligned with respect to the desired locations, and, in particular, with respect to features previously laid down on the same substrate. The exposed substrate, now labeled W'' is unloaded from the apparatus at step 220, to eventually undergo etching or other processes, in accordance with the exposed pattern.

[0057] The skilled person will know that the above description is a simplified overview of a number
35 of very detailed steps involved in one example of a real manufacturing situation. For example, rather than measuring alignment in a single pass, often there will be separate phases of coarse and fine

measurement, using the same or different marks. The coarse and/or fine alignment measurement steps can be performed before or after the height measurement, or interleaved.

[0058] The patterning device (e.g. reticle or mask) MA is handled in a similar way in which the substrate W is handled. For example, a reticle MA may be loaded into a lithography apparatus (e.g. a EUV system) from a clean and particle-tight reticle storage container, as disclosed in US7839489 and EP1519233B1 (both of which are hereby incorporated by reference). Referring to Figures 1, 2 and 3, once loaded into the system, the reticle MA is mounted onto the reticle stage such that the reticle MA can be accurately positioned, with respect to the path of the radiation beam 56 by using the positioner PM and position sensor PS1. The reticle alignment will be performed at a time point determined by a system controller, for example at step 212. Once requested by the controller, the reticle is automatically aligned with respect to its support MT via one or more reticle markers. When patterns of the reticle are accurately aligned with respect to the desired locations, the system will be ready for lithographic exposure.

[0059] Even though reticles are generally cleaned as much as is possible, or at least practical, before being placed into a storage container and subsequently loaded into a lithographic system, the imperfect cleaning process, e.g., which may leave chemical residues, coupled with imperfect environmental conditions, e.g., humidity, still results in external molecules (e.g., water and organic molecules) being absorbed into and/or salt deposits being formed on one or both surfaces of the reticle during handling, transportation and/or storage. For example, while EP1519233B1 proposes several precautionary measures to reduce the risk of contamination of the storage space, such as intermediate vacuum and dedicated coupling structure, the imperfect coupling between the transfer container and the storage container would inevitably bring particles, water and organic molecules from the external environment into the storage container where the reticle is stored. In comparison to a fresh reticle, the situation becomes much worse if an existing reticle is to be reused without going through any cleaning process again.

[0060] Some of those molecules and particles, which have managed to enter the system, would be chemisorbed to the surfaces of the reticle and self-assembled to form various localized clusters around some active sites. For example, water molecules are chemisorbed onto a reticle surface via partial dissociation of water molecules into OH and H radicals. The resultant OH and H radical groups are bound tightly to the active sites of the surface. As a result of this chemisorption process, water molecules can remain on such a surface for a very long time. These self-assembled clusters could also combine with each other to form a thin layer of coating, such as a thin layer of water coating or hydrocarbon coating. The water clusters/coating, together with existing salt deposits, could further strengthen the binding between particles and reticle surfaces. Consequently, the typical cleaning method using a gas jet is ineffective for removing these particles.

[0061] Depending on their sizes, particles and salt deposits of reticle surfaces could seriously affect or even block some of existing pattern features, resulting in large patterning errors (e.g. overlay errors,

deformations such as broken lines and/or unwanted contacts) or even false patterns on the substrate W. Furthermore, due to the high water absorption coefficient at EUV wavelengths, the thin water coating formed on the reticle surfaces may attenuate the EUV beam and lead to an insufficient radiation intensity for patterning the substrate. Additionally or alternatively, if the thin water coating is not homogeneous, for example scattered water clusters, the transverse beam profile of the EUV light can be altered or modulated by inhomogeneous attenuation (as a result of inhomogeneous water absorption) across the full spot area of the impinging EUV light. The inhomogeneous attenuation across the EUV beam could in turn change the focusing characteristics of the EUV light in the projection system PS and lead to variations in patterning, e.g. critical dimension (CD) variation. Inconsistent patterning would negatively impact the yield of the EUV system.

[0062] A 'moist' reticle, i.e. with a thin layer of water molecules on one or both surfaces, has a negative impact on the CD of the printed wafer features. Studies have revealed that the absorbed water molecules gradually disappear from the reticle surfaces after performance of a certain number of EUV exposures using the same reticle. A result of this removal of absorbed water molecules is that the CD of the printed wafer features tends to drifts while this is happening. Such CD drift eventually stabilizes when the reticle is fully dehumidified and all the absorbed water molecules are completely removed. For example, in a typical EUV lithography apparatus, it may take as many as 50 wafer exposures until all the absorbed water molecules are removed from the reticle surfaces such that the CD drift is stabilized and a consistent patterning performance is obtained. The number of exposure required to fully dehumidify a reticle may be dependent on applications and operating conditions in a lithography apparatus.

[0063] Several methods have been employed for dehumidifying reticles in a lithography apparatus. In one of such methods, a 'moist' reticle may be loaded into the lithography apparatus well in advance so as to ensure the reticle will be completely dried by the time lithographic exposures start. However, such a dehumidification process may take an impractical length of time to complete, for example several days.

[0064] In a second method, instead of loading the 'moist' reticle several days prior to commencement of a lithographic exposure, the 'moist' reticle is loaded into the lithography apparatus whenever it is needed and subsequently dehumidified by running a dummy lot of wafers. When these dummy wafers start to show a consistent CD, indicative of the reticle being completely dry, the lithography apparatus can then be regarded as being ready for running production wafers. Alternatively, in a third method, a dedicated exposure procedure is created such that after being loaded into the lithography apparatus, the 'moist' reticle will be exposed by, for example, a EUV radiation beam for a certain amount of time (in either a continuous or an intermittent manner) until the specific part of the reticle on which the EUV light impinges is dry. However, such a dedicated exposure procedure would have to be repeated a plurality of times, for example 25, or 50, in order to ensure the full surface area of the reticle is dehumidified. As such, all of these methods have a high throughput penalty. The amount

of time required for loading and dehumidifying a new reticle is still significant and can account for a large percentage of the total usage time of the reticle. Hence the system throughput is greatly reduced. In some cases, the throughput of a EUV lithography apparatus can be reduced by as much as 20%.

[0065] The patent publication JP2004170802(A) discloses a different method in which a dedicated drying apparatus comprising a heater or an IR lamp is used outside a lithography apparatus. After being taken out from a storage container, a reticle is firstly transferred into the drying apparatus where it is dehumidified. Subsequently, the dry reticle is transferred into the lithography apparatus for exposure. Because the dehumidifying mechanism of this method is based on heating, a significant amount of time is required for the 'hot' reticle to settle thermally via passive cooling, i.e. reaching a thermal equilibrium with the ambient temperature, in order to prevent thermally induced overlay errors.

[0066] A surface treatment apparatus is disclosed herein which provides an efficient way for addressing the aforementioned problems. The apparatus is configured for surface treatment of substrates such as patterning devices/reticles (for patterning a beam to expose a pattern on a wafer) or the wafers on which the pattern is exposed, and comprises one or more support structures for holding one or more substrates, and at least one ultraviolet (UV) light source which is configured to emit UV radiation. The surface treatment apparatus may be contained in a housing, box or any type of receptacle which is at least partially enclosed. For example, a surface treatment apparatus, which is at least partially enclosed in a receptacle, may comprise a modular unit for a lithography apparatus, such that the surface treatment apparatus is operated within the vacuum environment of the lithography apparatus but can be assembled and/or serviced in a non-vacuum environment, e.g. outside of the lithography apparatus. Alternatively, the surface treatment apparatus may be fully integrated within the patterning device system PD of the lithography apparatus. The following embodiments will now be described in the context of treating patterning devices or reticles, but are equally applicable to treatment of wafers.

[0067] In contrast to conventional dehumidifying mechanisms which rely on heating and/or evaporating, the proposed surface treatment apparatus may use high energy UV photons, e.g. in the vacuum UV (VUV) wavelength range of 10 - 200 nm (and more specifically 10-170nm), emitted from the UV light source. The high energy UV photons can effectively break the O-H bonds of the absorbed water (H₂O) molecules and photo-dissociate such H₂O molecules into OH and H radicals. In parallel with the photo-dissociation process, the high energy UV photons can also break the strong bindings formed between the OH and H radical groups and the active sites of the surface. This allows the OH and H radical groups to be released from the reticle surface and subsequently carried away by the surrounding gas flow, e.g. a dry nitrogen (N₂) gas or a dry hydrogen (H₂) gas. Therefore, the use of UV radiation dehumidifies the surfaces of a reticle by removing the absorbed water molecules in a 'cold' and more controlled manner.

[0068] Furthermore, the use of UV radiation also allows certain surface contaminants to be simultaneously removed such that the after treatment, the reticle surfaces will be both dry and clean. Surface contaminants, such as small particles (for example having a size ranging from 10nm to 10µm)

which are bound to the reticle surface by, for example salt deposits or capillary forces, are difficult to remove by conventional approaches, e.g., using a gas jet to blow away fall-on particles that are loosely bound to the reticle surface. This difficulty can be overcome by exposing the surface to UV radiation, which can 1) dissociate the underlying salt deposits and water molecules and/or 2) break the enhanced
5 bindings formed between particles and such salt deposits and water molecules. The particles bound by such salt deposits and/or water molecules can then be released from the reticle surface and subsequently carried away by the surrounding gas flow. Therefore, in comparison to 'hot' dehumidifying methods, such an approach provides a 'cold' and therefore faster approach for dehumidifying reticle surfaces which additionally provides the additional effect of simultaneous surface cleaning.

10 **[0069]** The surface cleaning capability of the system can be further extended by introducing particular background gases, such as for example Oxygen (O_2) and/or Hydrogen (H_2) molecules, into the system. Such background gases, in combination with appropriate UV photon energies (with respect to chemical bonding energy of the gas molecules) can be used to photo-dissociate such gas molecules. For example, the photon energy needed for dissociating O_2 molecules is similar to that of H_2O molecules
15 which corresponds to a UV wavelength shorter than 170 nm. Whereas higher photon energies (corresponding to a UV wavelength shorter than 100 nm) will be required to photo-dissociate H_2 molecules. After the photo-dissociation process, highly reactive radicals, e.g. H and O, are generated; these radicals will react with certain surface contaminants, aiding their removal from the treated surface.

[0070] For example, O_2 gas may be used as the background gas and the UV source may emit
20 radiation at (at least) a first UV wavelength and a second UV wavelength. In such an example, the O_2 molecules will be dissociated into O radicals by UV radiation at the first UV wavelength. Some of the O radicals will combine with O_2 molecules and form ozone (O_3) molecules which will act as a strong oxidizing agent. Additionally, some of those O_3 molecules will be further dissociated into O radicals by UV radiation at the second UV wavelength. The generated highly reactive O radicals and O_3 molecules
25 will then oxidize carbon containing organic substances, e.g. hydrocarbon clusters or coating and convert them into gaseous molecules (e.g. CO or CO_2) which will be subsequently removed from the system via gas circulation. For example, the fresh background gas may enter into the system from a gas inlet and after circulating the system, the background gas carrying the released surface substances may exit the system via a gas outlet. The pressure of the surface treatment apparatus may return from the initial
30 vacuum condition to the ambient pressure of the lithography apparatus. In a similar manner, H_2 gas can also be used as a background gas which, when exposed to UV radiation at a suitable UV wavelength (e.g. <100 nm), will be dissociated into H radicals. The H radicals can react with organic substances and/or particles, or with metal containing substances such as metal particles, and hence remove these from the surface.

35 **[0071]** Figure 4 illustrates a surface treatment apparatus 400 for patterning devices (e.g. a reticles) according to a first embodiment. The surface treatment apparatus is partially enclosed in a housing or chamber 470 which forms a detachable modular unit in a lithography apparatus. Such a detachable

modular unit may be located inside the illumination system IL, the projection system PS or the patterning device system PD of a lithographic apparatus such as illustrated in Figure 2, and share the vacuum environment with one or all of these sub-systems. The surface treatment apparatus may be configured such that when a current patterning device is being used for an exposure and a request for the next patterning device is made by, for example the controller of the lithographic apparatus, this next reticle will be a treated patterning device, having been treated by the surface treatment apparatus 400. This treated patterning device will then be transferred from the surface treatment apparatus to the desired exposure location in the patterning device system PD. Referring to Figure 2, the step of performing surface treatment and subsequent reticle transfer should be completed before the reticle alignment step 212 starts.

[0072] The support structures can be implemented in various different designs and can hold patterning devices in various different ways. In the first embodiment, the support structure 420, comprising two supporting arms which are connected to the walls of the chamber 470, is elevated to a certain height from the bottom. The two arms of the support structure 420 hold a portion of the peripheral region of the back surface 410b of the reticle 410. In such a manner, both the front (top) 410a and the back (bottom) 410b surfaces of the reticle 410 are accessible. It is noted that the location of the support structure 420 is not restricted. In a different embodiment, the support structure 420 may be located at any other suitable location, for example at the bottom of the chamber, such that only the top surface 410a of a reticle 410 is accessible. Alternatively, in another embodiment, a support structure 420 is located at the top of the chamber and the reticle 410 is held inverted such that at least a portion of a peripheral region of the front surface 410a of a reticle 410 is in contact with the support structure 420. As illustrated in Figure 4, the support structure 420 is configured such that the support structure 420 holds only a single patterning device. However, there is no restriction as to how many support structures can be placed in one chamber and how many patterning devices can be held by a single support structure. For example, in other embodiments, a single support structure is provided which supports a plurality of patterning devices, or a plurality of support structures are provided where each is configured to support only a single patterning device or one or more of the plurality of support structures can each support a plurality of patterning devices.

[0073] The UV light source can comprise either an incoherent light source (e.g. a gas-discharge UV lamp) or a coherent light source (e.g. a UV laser). The UV radiation which is emitted from the UV light source should cover at least a portion of the vacuum UV (VUV) wavelength region, i.e. 10 - 200 nm. In some embodiments, the UV radiation should cover at least a portion of the UV wavelength range shorter than 170 nm and/or 100 nm. One or more UV light sources can be located at any suitable locations inside the chamber. For example, in the example illustrated in Figure 4, a first UV light source 440a and a second UV light source 440b are provided the top and bottom of the chamber 470 respectively, such that both the front and the back surfaces 410a, 410b of a reticle 410 can be dehumidified and cleaned simultaneously. The UV light sources 440a, 440b are configured to emit a

divergent UV light 450a, 450b which is able to cover the entire useful surface area (e.g., all except the peripheral handling area 460) of a reticle 410 at the plane in which the reticle surface to be treated is located.

[0074] One or more transport gas inlets or nozzles may be provided to provide a gas flow to remove particles. In the example illustrated in Figure 4, four transport gas supply nozzles 430a-430d located in the vicinity of the reticle surfaces to generate gas flows for carrying away any substances (e.g. particles, OH and H radicals) released from the reticle surfaces 410a, 410b. Here, two nozzles are allocated for each surface 410a, 410b of the reticle 410. The two gas flows produced by two respective nozzles propagating in opposite directions meet at the center of each reticle surface, where they collide and flow away from the surface towards one or more outlets 480a, 480b, 480c, 480d. The number, location and/or arrangement of transport gas supply nozzles and/or outlets is not limited to four and will be application dependent. When the surface treatment process is complete and a request for reticle transfer is made, the dry and clean reticle 410 will be transferred (e.g., by a transportation device) from the surface treatment apparatus into the reticle compartment (e.g., patterning device chamber PD).

[0075] Furthermore, a reactive background gas may optionally be introduced into the vacuum environment shared between the illumination system IL, the patterning device system PD, the projection system PS and the surface treatment apparatus and in particular within the chamber 470. This background gas supply may be the same or distinct from the transport gas supply (for transporting contaminants out of the chamber) provided by gas nozzles 430a-430d. For example, the background gas, e.g., a dry O₂ gas or a dry H₂ gas may be introduced by gas nozzles 430a-430d, or by a separate gas nozzle 490, into the chamber 470. After circulation, the background gas carrying the released substances for reticle surfaces will eventually exit the chamber via gas outlets 480a-480d. It is noted that the number, location and/or arrangement of gas nozzles and gas outlets can differ from illustrated and described herein, and be different for different applications. The provision of the background gas can improve the cleaning capability by removing many additional contaminants (e.g. carbon and/or metal containing particles) which cannot be removed by using UV radiation alone. After the UV surface treatment, the vacuum environment of the system should be recovered to allow the after-treatment reticle to be exposed.

[0076] Since a UV surface treatment is a 'cold' process, the long and uncontrolled thermal settling time required by a 'hot' surface dehumidifying method is successfully circumvented and as such the speed of the UV surface treatment is significantly improved. Instead of waiting several hours for a 'hot' after-treatment reticle to completely settle, the UV surface treatment can be accomplished, for example, in only tens of seconds. Therefore, after being transferred into the reticle compartment for exposure, the treated reticle can be immediately used for exposure (e.g., as soon as the reticle alignment step 212 is completed). The amount of time required for the UV surface treatment may be less than 10s, 20s, 30s, 40s or 50s, for example. Depending on the location of the surface treatment apparatus within a lithography apparatus and the type of the transportation device, the amount of time required for

transferring a reticle internally to the reticle stage (for exposures) may be similar to, or shorter than, that required for loading a reticle from an external storage container. Loading a dry and clean reticle within the vacuum environment of the lithography apparatus prevents such a reticle being re-humidified and/or re-contaminated when loading it from a location outside the lithography apparatus. The timing for commencement of a UV surface treatment can be controlled and scheduled by the controller of the lithography apparatus. For example, while a current reticle is being exposed, the next reticle may be scheduled to simultaneously commence a surface treatment process, such that this next reticle has completed treatment and is available by the time that use of the current reticle is finished.

[0077] Figure 5 illustrates a surface treatment system 500 according to a further embodiment. This configuration is particularly applicable for EUV lithography where reflective reticles are typically used. In comparison to the embodiment illustrated in Figure 4, the two support structures 520a, 520b are not elevated at a certain height respect to the bottom of the chamber 570 but instead fixed directly to the bottom of the chamber 570. At least a portion of the peripheral region of the back surface 510b of the reticle 510 is in contact with the support structures 520a, 520b such that the reticle is stably held. A single UV light source 540 is used to illuminate only the front surface 510a of the reticle 510 with UV light 550. Gas supply nozzles 530a, 530b are provided to generate a gas flow for removal of contaminants and molecules, removed from the surface, out of the chamber 570, e.g., via outlets 580a, 580b. These gas supply nozzles may additionally provide a reactive background gas, or else one or more additional nozzles 590 may provide such a background gas.

[0078] Note that the actual arrangement may differ from that illustrated in the particular example. For example, it may be preferred that the most sensitive surface for particle contamination should point down rather than up (because of gravity) and therefore the reticle 510 may be inverted from that shown (front surface 510a facing down), with the UV light source 540 illuminating this surface from below. Also, it should be kept in mind that the clamped backside of the reticle should be kept clean and dry.

[0079] Instead of being comprised within a detachable modular unit, the surface treatment apparatus can be fully integrated into the existing environment in the patterning device system PD where a to-be-exposed patterning device is held. Figure 6 illustrates an integrated version of the surface treatment apparatus according to another embodiment. In this case, the support structure 620 (corresponding with support structure MT of Figure 2) of the patterning device system PD acts as the support structure 620 of the surface treatment apparatus. The existing gas flows in the patterning device system PD are used to remove the surface substances released during the UV surface treatment.

[0080] As shown in Figure 6, a reflective reticle 610 is held by a support structure 620 with the front surface facing towards the projection EUV beam. A UV light source 640 (separate from the EUV source) is located at a certain distance to the reflective front surface of the reticle and sits in-between the incident 56 and the reflected 57 EUV beams. The UV light source 640 emits a divergent UV beam 650 toward the top surface of the reticle 610. The spot size of the divergent UV beam 650 is sufficiently large to cover the reticle surface area. Two gas supply nozzles (not shown) located at the two edges of

the reticle surface are used to create two gas flows which collide at the center of the reticle surface and move away (downwards) from the surface. Depending on applications, there may be many other different arrangements for gas supply nozzles. For example, according to another embodiment, the patterning device may be held differently in a different lithography apparatus and hence may desire a different number of nozzles to be placed at different locations.

[0081] After a reticle 610 is loaded into the patterning device system PD and mounted onto the support structure 620, the UV light source will be enabled by the system controller to perform surface treatment including dehumidification and cleaning. The released substances, e.g. particles, gaseous molecules, OH and H radicals, will be taken away by the surrounding gas flows and eventually removed from the system. Comparing to the embodiments of Figures 4 and 5, where the surface treatment is performed in a separate compartment or modular unit, the in-situ UV surface treatment in this embodiment further simplifies the system design by removing the need of the transportation device. The overall process time from starting the UV surface treatment to being loaded and ready for exposure may be similar to that in the first two embodiments.

[0082] The above embodiments and examples describe embodiments for treatment of patterning devices/reticles. It should be note that many of the issues discussed can also affect other substrates, and in particular the substrates being patterned (the wafers). Therefore, the methods and devices described herein should be understood to include equivalent methods and devices for treatment of such wafers, e.g., prior to being patterned.

[0083] Although specific reference may be made in this text to the use of lithographic apparatus in the manufacture of ICs, it should be understood that the lithographic apparatus described herein may have other applications. Possible other applications include the manufacture of integrated optical systems, guidance and detection patterns for magnetic domain memories, flat-panel displays, liquid-crystal displays (LCDs), thin-film magnetic heads, etc.

While specific embodiments of the invention have been described above, it will be appreciated that the invention may be practiced otherwise than as described. The descriptions above are intended to be illustrative, not limiting. Thus it will be apparent to one skilled in the art that modifications may be made to the invention as described without departing from the scope of the claims set out below.

CLAIMS

1. A surface treatment apparatus for dehumidifying substrates, comprising:
one or more support structures for supporting one or more substrates;
5 one or more ultraviolet illumination sources configured to emit ultraviolet illumination, and being operable to treat said at least one surface of said one or more substrates while said one or more substrates being supported by said one or more support structures;
wherein said one or more ultraviolet illumination sources are distinct from an exposure source and not operable to emit exposure illumination for exposing a pattern on a wafer.
- 10 2. A surface treatment apparatus as claimed in claim 1, the one or more ultraviolet illumination sources are configured to emit a first UV wavelength and a second UV wavelength.
3. A surface treatment apparatus as claimed in any preceding claim, further comprising a
15 plurality of ultraviolet illumination sources, each of the respective ultraviolet illumination sources being configured to emit ultraviolet illumination towards a respective section of the at least one surface.
4. A surface treatment apparatus as claimed in any preceding claim, wherein said ultraviolet illumination from said one or more ultraviolet illumination sources comprises one or more wavelengths
20 in a range between 10nm and 200 nm.
5. A surface treatment apparatus as claimed in any of claims 1 to 3, wherein said ultraviolet illumination from said one or more ultraviolet illumination sources comprises one or more wavelengths in a range between 10nm and 170nm.
- 25 6. A surface treatment apparatus as claimed in any of claims 1 to 3, wherein said ultraviolet illumination from said one or more ultraviolet illumination sources comprises one or more wavelengths in a range between 10nm and 100nm.
- 30 7. A surface treatment apparatus as claimed in any preceding claim, wherein at least one of said one or more support structures is operable to support a plurality of substrates.
8. A surface treatment apparatus as claimed in any preceding claim, further comprising one or more transport gas supply sources configured to create one or more transport gas flows for transporting
35 away particles released from said one or more substrates during said surface treatment.

9. A surface treatment apparatus as claimed in claim 8, wherein said one or more gas flows comprise one or more of a Nitrogen (N₂) gas or a Hydrogen (H₂) gas.

10. A surface treatment apparatus as claimed in any preceding claim, comprising one or more background gas sources for supplying a reactive background gas into the surface treatment apparatus.

11. A surface treatment apparatus as claimed in claim 10, wherein said reactive background gas, or products thereof resultant from the effect of said ultraviolet illumination on the background gas, is operable to aid removal of one or more contaminant particles on said at least one surface of said one or more substrates.

12. A surface treatment apparatus as claimed in claim 11, wherein said background gas comprises one or more of Oxygen or Hydrogen (H₂) gas.

13. A surface treatment apparatus as claimed in claim 2 and 11, wherein said background gas comprises Oxygen and the first UV wavelength is configured to dissociate Oxygen into O radicals.

14. A surface treatment apparatus as claimed in any preceding claim, wherein each of said substrates comprises a patterning device for patterning a wafer in a lithographic process;

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15. A surface treatment apparatus as claimed in claim 14, wherein said patterning device comprises one or more of: a reticle, a programmable mirror array and a programmable LCD panel.

16. A surface treatment apparatus as claimed in any of claims 1 to 13, wherein each of said substrates comprises a wafer for exposing a pattern thereon in a lithographic process.

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17. A surface treatment apparatus as claimed in any preceding claim comprising a housing for at least partially enclosing at least said one or more support structures and said one or more ultraviolet illumination sources.

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18. A surface treatment apparatus as claimed in claim 17, wherein said housing comprises a modular housing configured to interface with one or more other housings of a lithographic apparatus such that said surface treatment apparatus and said one or more other housings share a common vacuum or partial vacuum environment.

35

19. A surface treatment apparatus as claimed in claim 14, 15 or 16, wherein said surface treatment apparatus is comprised within the appropriate chamber within a lithographic apparatus, the appropriate chamber being:
where the substrate comprises a patterning device, a patterning device chamber such that said one or
5 more support structures comprises a patterning support for supporting the patterning device during an exposure; or
where the substrate comprises a wafer, a wafer stage compartment, such that said one or more support structures comprises a wafer support for supporting the wafer during an exposure.
- 10 20. A lithographic apparatus comprising a surface treatment apparatus as claimed in any of claims 1 to 18, for treating the surface of one or more substrates prior to performing an exposure using or on said one or more substrates.
- 15 21. A lithographic apparatus as claimed in claim 20, wherein said surface treatment apparatus is at least partially enclosed in a modular unit and said modular unit is located within said lithography apparatus.
22. A lithographic apparatus as claimed in claim 21, wherein said modular unit is detachable from said lithography apparatus.
- 20 23. A lithographic apparatus as claimed in claims 20, 21 or 22, further comprising a transportation device to transfer a treated substrate from said modular unit to a desired location for performance of a lithographic exposure with said treated substrate.
- 25 24. A lithographic apparatus as claimed in any of claims 20 to 23, being operable to perform a surface treatment process using the surface treatment apparatus on a second substrate scheduled for use in a subsequent exposure, at least partially simultaneously with performing an exposure using a first substrate.
- 30 25. A lithography apparatus as claimed in claims 20, comprising a patterning device system, wherein said surface treatment apparatus is integrated within said patterning device system such that said patterning device system and said apparatus for surface treatment of substrates share same support structure.
- 35 26. A lithography apparatus as claimed in claims 20, comprising a wafer stage compartment, wherein said surface treatment apparatus is integrated within said wafer stage compartment such that

said wafer stage compartment and said apparatus for surface treatment of substrates share same support structure.

27. A lithography apparatus as claimed in claims any of claims 20 to 26 comprising an EUV or
5 DUV lithography system.

28. A method for treatment of at least one surface of one or more substrates used in a lithographic process, said treatment comprising at least dehumidifying said at least one surface, the method comprising:
10 illuminating the at least one surface with ultraviolet illumination, wherein said ultraviolet illumination is distinct from exposure illumination for exposing a pattern on a wafer.

29. A method as claimed in claim 28, wherein said ultraviolet illumination comprises one or more wavelengths in a range between 10nm and 200 nm.
15

30. A method as claimed in claim 28, wherein said ultraviolet illumination comprises one or more wavelengths in a range between 10nm and 170nm.

31. A method as claimed in claim 28, wherein said ultraviolet illumination comprises one or
20 more wavelengths in a range between 10nm and 100nm.

32. A method as claimed in any of claims 28 to 31, comprising generating one or more transport gas flows for transporting away particles released from said one or more substrates during said surface treatment.
25

33. A method as claimed in claim 32, wherein said one or more gas flows comprise one or more of a Nitrogen (N₂) gas or a Hydrogen (H₂) gas.

34. A method as claimed in any of claims 28 to 33, comprising supplying a reactive background gas during said treatment, such that said reactive background gas, or products thereof resultant from the effect of said ultraviolet illumination on the background gas, aids removal of one or more contaminant particles on said at least one surface.
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35. A method as claimed in claim 31, wherein said background gas comprises one or more of
35 Oxygen or Hydrogen gas.

36. A method as claimed in any of claims 28 to 35 comprising transporting each treated substrate to a substrate support within a substrate chamber.

37. A method as claimed in any of claims 28 to 36 comprising performing a lithographic exposure
5 to expose a pattern using or on said treated substrate.

38. A method as claimed in any of claims 28 to 37 wherein said performing a lithographic exposure using or on said treated substrate is performed at least partially simultaneously with treatment of a subsequent substrate.

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39. A method as claimed in any of claims 28 to 38, wherein each of said substrates comprises a patterning device for patterning a wafer in a lithographic process;

40. A method as claimed in any of claims 28 to 38, wherein each of said substrates comprises a
15 wafer for exposing a pattern thereon in a lithographic process.

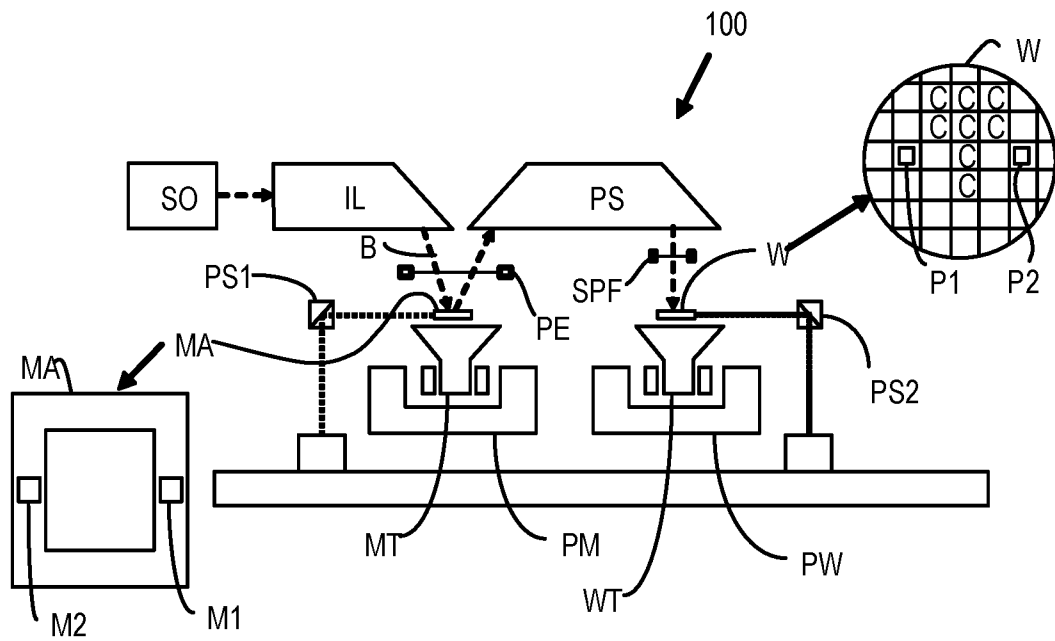


Fig. 2

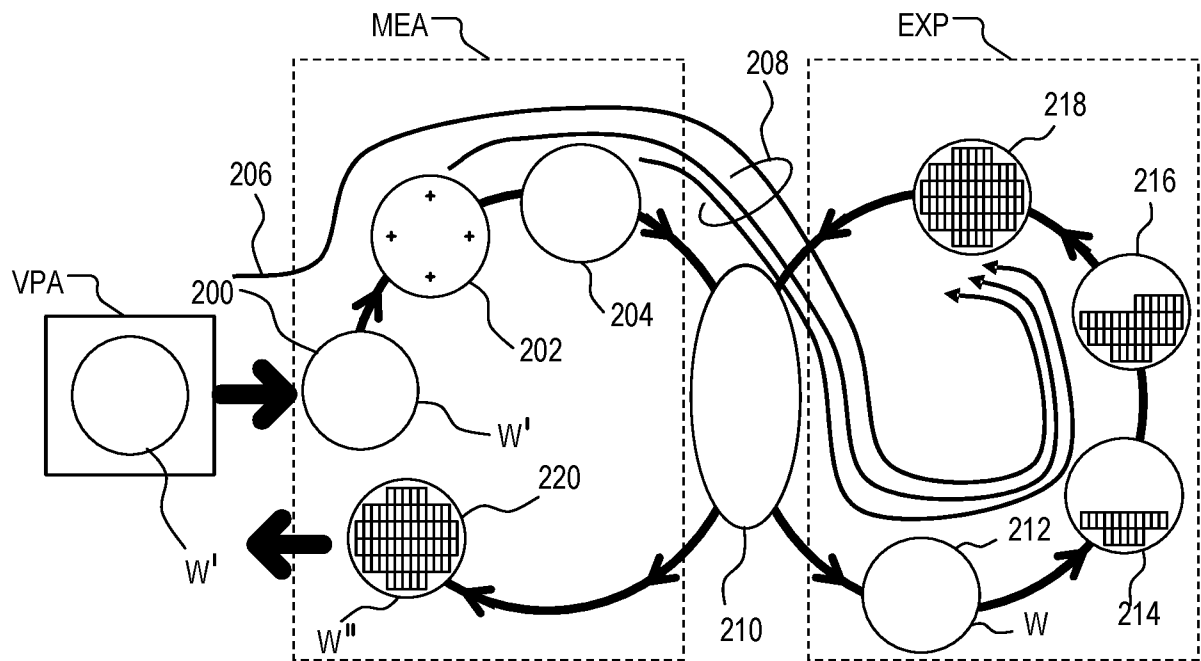


Fig. 3

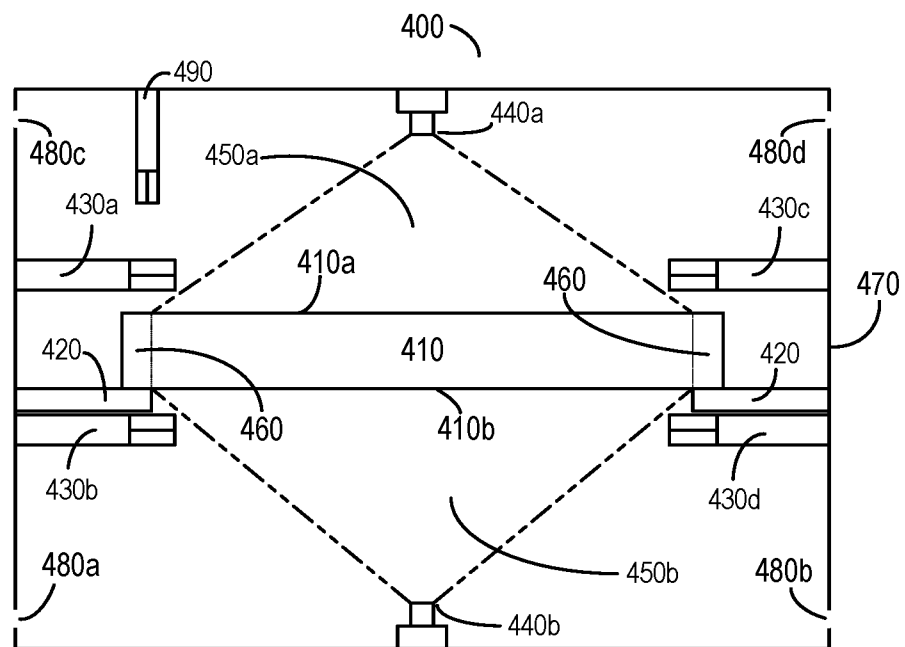


Fig. 4

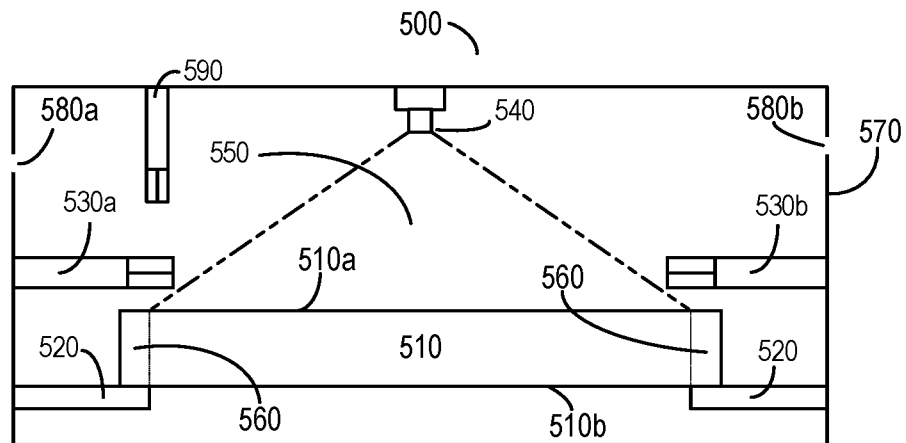


Fig. 5

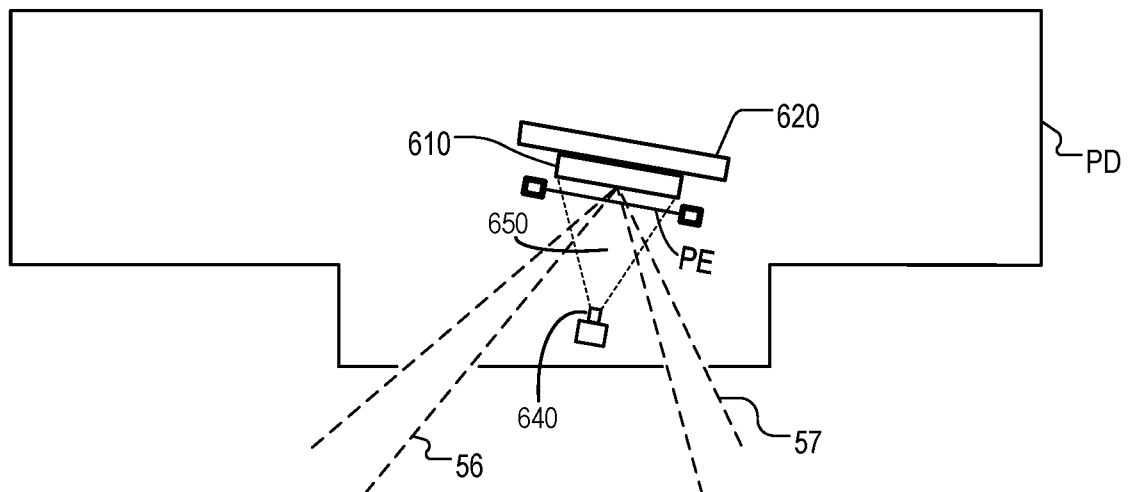


Fig. 6

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2020/064806

A. CLASSIFICATION OF SUBJECT MATTER

INV. G03F7/20 H01L21/67 G03F1/82
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)

G03F H01L

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, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 01/61409 A2 (SILICON VALLEY GROUP [US]) 23 August 2001 (2001-08-23)	1-15,17, 19-39
Y	page 6, line 28 - page 7, line 13; claims 1,8; figure 2 page 6, line 4 - line 15 page 8, line 3 - line 8 -----	16,18,40
X	US 6 842 221 B1 (SHIRAISHI NAOMASA [JP]) 11 January 2005 (2005-01-11)	1,20,28
Y	column 29, line 15 - line 34; claims 1-4,23,24; figures 1,9 column 5, line 12 - line 24 -----	18
Y	US 6 828 569 B2 (ASML NETHERLANDS BV [NL]) 7 December 2004 (2004-12-07) column 9, line 67 - column 10, line 4 -----	16,40
	-/--	



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"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

17 August 2020

Date of mailing of the international search report

04/09/2020

Name and mailing address of the ISA/

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Authorized officer

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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2020/064806

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 02/052345 A1 (NIPPON KOGAKU KK [JP]; SHIRAISHI NAOMASA [JP]) 4 July 2002 (2002-07-04) figure 1	18
A	----- US 2017/045832 A1 (MOLKENBOER FREEK THEODORUS [NL] ET AL) 16 February 2017 (2017-02-16) the whole document -----	1-40

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2020/064806

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 0161409	A2	23-08-2001	AU 3315501 A 27-08-2001
		EP 1256031 A2 13-11-2002	
		JP 2003523640 A 05-08-2003	
		KR 20030034043 A 01-05-2003	
		US 6387602 B1 14-05-2002	
		WO 0161409 A2 23-08-2001	
US 6842221	B1	11-01-2005	AU 2325900 A 04-10-2000
		KR 20020006670 A 24-01-2002	
		TW 473816 B 21-01-2002	
		US 6842221 B1 11-01-2005	
		WO 0055891 A1 21-09-2000	
US 6828569	B2	07-12-2004	CN 1474234 A 11-02-2004
		DE 60218802 T2 06-12-2007	
		EP 1312984 A2 21-05-2003	
		JP 4194831 B2 10-12-2008	
		JP 2003234287 A 22-08-2003	
		KR 20030075136 A 22-09-2003	
		SG 120897 A1 26-04-2006	
		TW I266960 B 21-11-2006	
		US 2003096193 A1 22-05-2003	
		US 2005112508 A1 26-05-2005	
WO 02052345	A1	04-07-2002	JP 4096246 B2 04-06-2008
		JP WO2002052345 A1 30-04-2004	
		WO 02052345 A1 04-07-2002	
US 2017045832	A1	16-02-2017	JP 2017520010 A 20-07-2017
		NL 2014602 A 31-03-2016	
		US 2017045832 A1 16-02-2017	
		WO 2015165705 A1 05-11-2015	