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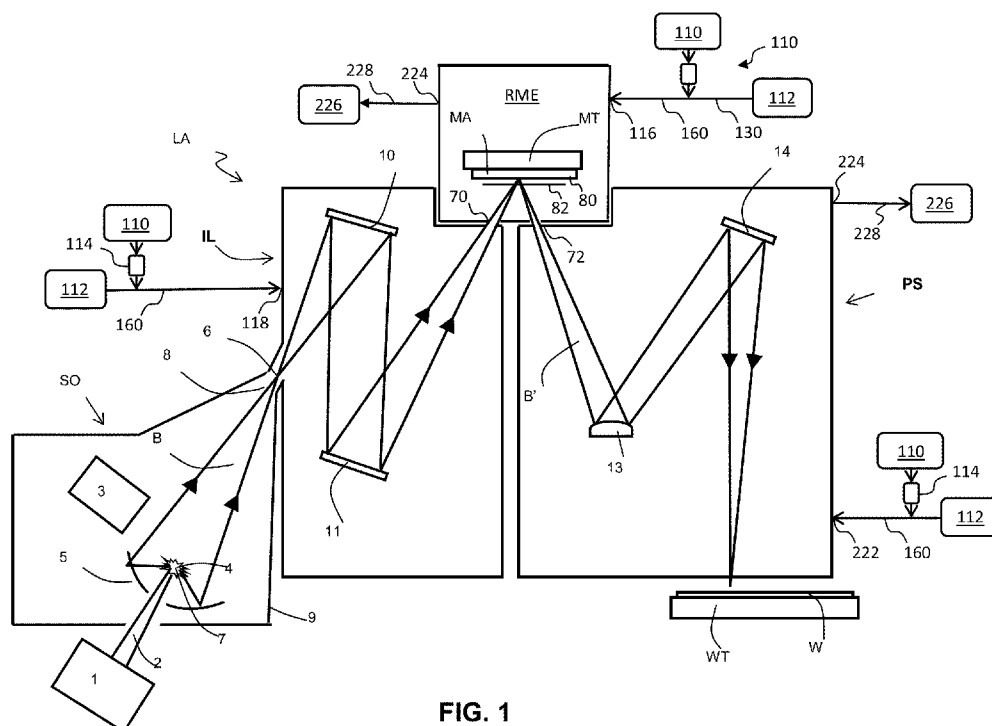


FIG. 1

(57) Abstract: The disclosure provides a method for preventing degradation of a material of an optical component for extreme ultraviolet light (EUV) lithography, the method comprising the steps of: arranging a wafer on a wafer table; producing extreme ultraviolet light using a source of extreme ultraviolet light; reflecting the extreme ultraviolet light towards the wafer via at least one reflective device, the at least one reflective device including a reticle device for providing a pattern to the extreme ultraviolet light; and stabilizing a material of the at least one reflective device by providing an oxygen containing gas.

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METHOD AND SYSTEM FOR PREVENTING DEGRADATION OF A MATERIAL OF AN OPTICAL COMPONENT FOR EUV-LITHOGRAPHY

5 CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority of EP application 21215476.9 which was filed on 17 December 2021, and which is incorporated herein in its entirety by reference.

FIELD

10 [0002] The present invention relates to a system and a method for limiting or preventing changes to material composition in plasma conditions. The surface may be, for instance, a surface in a lithographic apparatus. The surface may be, for instance, a wall or enclosure, an optical element, a protective layer, a mask, or a substrate. The plasma conditions may include an environment comprising hydrogen plasma.

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BACKGROUND

[0003] A lithographic apparatus is a machine constructed to apply a desired pattern onto a substrate. A lithographic apparatus can be used, for example, in the manufacture of integrated circuits (ICs). A lithographic apparatus may, for example, project a pattern at a patterning device (e.g., a mask) onto a layer of radiation-sensitive material (resist) provided on a substrate.

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[0004] As semiconductor manufacturing processes continue to advance, the dimensions of circuit elements have continually been reduced while the amount of functional elements, such as transistors, per device has been steadily increasing over decades, following a trend commonly referred to as 'Moore's law'. To keep up with Moore's law the semiconductor industry is chasing technologies that enable to create increasingly smaller features. To project a pattern on a substrate a lithographic apparatus may use electromagnetic radiation. The wavelength of this radiation determines the minimum size of features that are patterned on the substrate.

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[0005] In the electromagnetic spectrum, extreme ultraviolet is the most energetic part of the UV region. It runs from, typically, 100 to 10 nanometers, between x-ray radiation and deep or far-ultraviolet (DUV, 100 to 200 nm). For comparison, visible light runs from 700 to 400 nm, and, typically, UV radiation refers to light having a wavelength of 400 to 280 nm.

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[0006] Typical wavelengths currently in use for lithography are 365 nm (i-line), 248 nm (KrF), 193 nm (ArF) and 13.5 nm (EUV). A lithographic apparatus, which uses extreme ultraviolet (EUV) radiation, having a wavelength within a range of 4 nm to 20 nm, for example 6.7 nm or 13.5 nm, may be used to form smaller features on a substrate than a lithographic apparatus which uses, for example, radiation with a wavelength of 193 nm.

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[0007] EUV light generation devices may include, for instance, three kinds of devices. One device is a laser produced plasma (LPP) device that uses plasma generated by irradiating a target material with a pulse laser beam. Another device uses a discharge produced plasma (DPP) device that uses plasma generated by electrical discharge. Yet another device uses a synchrotron radiation (SR) device that uses synchrotron radiation.

[0008] EUV radiation itself is readily absorbed by air and other gasses. As a result, the EUV light has to travel through a high-quality vacuum from the moment it is generated to the moment it hits the wafer. It also means that instead of lenses, curved reflective mirrors are typically required. A traditional lens or photomask would absorb too much light, so the mask or reticle needs to be reflective as well.

[0009] For EUV radiation, reflecting optics having moderate efficiency ($> 60\%$) can be constructed using multilayer films. The multilayer films may comprise multiple intermittent layers of, for instance, silicon (Si) and molybdenum (Mo). The multilayer film is typically deposited on a substrate, for instance comprising glass or a glassy material.

[0010] As mentioned above, the optics section of the EUV lithography apparatus may operate in a vacuum. Said vacuum may be in the order of 5 Pa. The vacuum not only consists of removing air, but may include the replacement of air with a protective gas. Said gas may comprise hydrogen. The high energy of the EUV light, which may be in the order of 90 eV, may break the hydrogen bonds, resulting in hydrogen radicals inside the optical section. Said hydrogen radicals readily bond with a wide range of components. Said components are typically unwanted. The resulting newly formed substances – bonded with hydrogen – are typically gaseous and can be removed from the lithography apparatus, thereby removing the unwanted substances from the optics section. The hydrogen atmosphere thus has a cleaning function for the scanner optics.

[0011] A problem may arise when the hydrogen radicals become ionized, forming a hydrogen plasma. The EUV radiation inside the optics, and in addition the plasma of the EUV source, is sufficiently powerful to ionize hydrogen and hydrogen radicals. In the plasma conditions in the EUV light generation device and optical section, some surfaces have a tendency to form volatile components. Said surface include silicon and silicon-rich surfaces - including oxidized silicon, such as SiO_2 . When exposed to hydrogen plasma, or bombarded with hydrogen ions, silicon in or on the surfaces may form substances such as SiH_4 . This results in loss of silicon from the surface.

[0012] US2021124275 discloses an extreme ultraviolet light condensation mirror including a substrate, a multi-layer reflective film on the substrate configured to reflect extreme ultraviolet light having a wavelength of 13.5 nm, and a protective film on the multi-layer reflective film. The protective film includes an silicon oxide layer on the multi-layer reflective film and a titanium oxide layer on the silicon oxide layer having one surface exposed. US2021124275 also discloses an exemplary schematic configuration of an extreme ultraviolet light generation device.

[0013] The protective layer of the mirrors, for instance comprising titanium oxide or alternative materials such as ruthenium, typically comprises a material having an atomic weight sufficient to

withstand impact of high energy hydrogen ions from the plasma. Thus, the surface of the mirrors can be protected. However, the substrate of the mirrors, which is typically made of silicon rich material such as glass, is also exposed to the hydrogen plasma and may be negatively impacted.

[00014] The same holds for some other surfaces inside the lithography apparatus. For instance, unlike conventional lithography machines, the mask or reticle for EUV lithography is typically also a reflective device. A reflective surface of the mask can be covered by a protective layer, which may be referred to as pellicle. Unlike the mirrors, the protective layer of the mask has a limited range of suitable materials, able to provide sufficient transmission of EUV radiation. As a result, said layer typically comprises silicon, or is entirely made of silicon. As the protective layer is exposed to hydrogen plasma, said pellicle layer suffers from the formation of volatile SiH_4 and loss of silicon over time as described above. The decreasing amount of silicon in the protective layer changes EUV transmission thereof, which may result in dose errors. Also, the removal of silicon limits lifetime of the mirrors or reticle. The volatile components as formed, such as SiH_4 , may decompose and result in uneven deposition of silicon on the mirrors, reducing the accuracy of the reflections and of the resulting pattern projected on the wafer.

[00015] US2003147058A1 discloses reflective X-ray optical system components. The components suppress contamination (e.g. carbon contamination) of their reflective surfaces during use. The multilayer film comprises alternating layers of first and second substances configured so as to confer high reflectivity to incident X-radiation (including perpendicularly incident radiation). The multilayer film includes a protective layer (formed of a material including a photocatalytic material) desirably formed on the uppermost layer of the multilayer film. If the optical component is a reticle, a patterned absorbing-body layer covers at least a portion of the multilayer film. A protective layer can be formed between the multilayer film and the absorbing-body layer, or in a blanketing manner over units of the absorbing-body layer and exposed portions of the multilayer film. Surficial contamination is removed by irradiating the protective layer with IR or visible light, in an oxygen-containing atmosphere.

[00016] US2006192158A1 discloses relates to a method for preventing contamination on the surfaces of optical elements comprising a multi-layer system, during the exposure thereof to radiation at signal wave lengths in an evacuated closed system comprising a residual gas atmosphere, whereby the photocurrent generated by means of photo emission from the radiated surface of the multi-layer system is measured. The photocurrent is used to regulate the gas composition of the residual gas. The gas composition is altered according to at least one lower and one upper threshold value of the photocurrent. The invention also relates to a device for regulating the contamination on the surface of at least one optical element during exposure and an EUV-lithographic device and a method for cleaning the surfaces of the optical elements contaminated by carbon. According to US2006192158A1, when the composition of the residual gas atmosphere is modified by altering the partial oxygen pressure, either the oxidation process or the carbon deposition process is favored. The partial oxygen pressure is

changed by adding either oxygen or oxygen-containing gases. By increasing the partial oxygen pressure, the equilibrium is altered toward oxidation, which reduces the carbon-containing deposits.

[00017] Although the methods disclosed in US2006192158A1 and US2003147058A1 generally work well, the methods remove contamination. In other words, before contamination can be removed, there is contamination. Also, the method of US2006192158A1 and US2003147058A1 are unsuitable to prevent the formation of silane (SiH_4) and the associated problems as described above.

[00018] It is an object of at least one embodiment of at least one aspect of the present invention to obviate or at least mitigate at least one of the above identified shortcomings of the prior art.

SUMMARY

[00019] The disclosure provides a method for preventing degradation of a material of an optical component for extreme ultraviolet light (EUV) lithography, the method comprising the steps of:

- arranging a wafer on a wafer table;
- producing extreme ultraviolet light using a source of extreme ultraviolet light;
- reflecting the extreme ultraviolet light towards the wafer via at least one reflective device, the at least one reflective device including a reticle device for providing a pattern to the extreme ultraviolet light; and
- stabilizing a material of the at least one reflective device by providing an oxygen containing gas.

[00020] In an embodiment, the oxygen containing gas comprises hydrogen peroxide (H_2O_2).

[00021] In an embodiment, the material comprises silicon.

[00022] In an embodiment, the reticle device comprises a reticle provided with a pellicle arranged in parallel to the reticle, wherein the reticle device is arranged in a reticle mini-environment, the step of stabilizing the material at least comprising providing the oxygen containing gas to the reticle mini-environment.

[00023] In an embodiment, the step of providing the oxygen containing gas to the reticle mini-environment comprises flowing the oxygen containing gas along the pellicle.

[00024] In an embodiment, the step of providing an oxygen containing gas comprises:

- providing a flow of hydrogen containing gas;
- adding the oxygen containing gas to the flow of hydrogen.

[00025] In an embodiment, the step of adding the oxygen containing gas to the flow of hydrogen comprises:

- providing a source of the oxygen containing gas, the source having an outlet provided with a membrane;
- contacting the flow of hydrogen containing gas with an outer surface of the membrane.

[00026] In an embodiment, the step of adding the oxygen containing gas to the flow of hydrogen comprising the step of:

- controlling the amount of oxygen containing gas added to the flow of hydrogen by adjusting the flow rate of the hydrogen as a function of said outer surface of the membrane.

[00027] According to another aspect, the disclosure provides an assembly for preventing degradation of a material of an optical component for extreme ultraviolet light (EUV) lithography, the assembly comprising:

- at least one optical component for reflecting the extreme ultraviolet light arranged in a vacuum chamber; and

- the vacuum chamber having at least one inlet for gas adapted to provide an oxygen containing gas to the at least one reflective device, and an outlet for the gas.

[00028] In an embodiment, the at least one reflective device includes a reticle device for providing a pattern to the extreme ultraviolet light, the reticle device comprising a reticle provided with a pellicle arranged in parallel to the reticle, at least one inlet for gas being adapted to direct a flow of the oxygen containing gas along the pellicle.

[00029] In an embodiment, the assembly comprises:

- at least one conduit connecting a source of hydrogen containing gas to the at least one inlet for gas;

- a source of the oxygen containing gas, having an outlet provided with a membrane, an outer surface of the membrane being exposed to the at least one conduit.

[00030] According to yet another aspect, the disclosure provides a lithographic system being adapted for the method or comprising the assembly as referenced above.

BRIEF DESCRIPTION OF THE DRAWINGS

[00031] Embodiments of the invention will now be described, by way of example only, with reference to the accompanying schematic drawings, in which:

- Figure 1 schematically depicts an embodiment of a lithographic system comprising a lithographic apparatus and a radiation source according to the disclosure;

- Figure 2 schematically depicts an embodiment of a lithographic apparatus according to the disclosure;

- Figure 3 schematically depicts a cross section of a reticle mini environment according to the disclosure; and

- Figure 4 schematically depicts a gas flow control scheme for providing an oxygen containing gas.

DETAILED DESCRIPTION

[00032] Figure 1 shows a lithographic system comprising a radiation source SO and a lithographic apparatus LA. The radiation source SO is configured to generate an EUV radiation beam B and to supply the EUV radiation beam B to the lithographic apparatus LA. The lithographic apparatus LA

comprises an illumination system IL, a support structure MT configured to support a mask assembly MA, a projection system PS and a substrate table WT configured to support a substrate W. The support structure MT and the mask assembly MA may be arranged in a dedicated container, which may be referred to as a reticle mini environment RME. The RME may be connected to the illumination system IL and to the projection system PS via openings 70, 72 respectively.

[00033] The mask assembly MA may comprise a patterning device 80 and a pellicle 82. The pellicle may be included in a frame configured to support the pellicle. The frame may be mounted on the patterning device 80 with a mount. The pellicle 80 may be separate from the patterning device. The pellicle may, for instance, comprise a thin film layer of a material absorbing ionized particles. The material may be, for instance, silicon or a silicon comprising compound. For an example of technical details of the patterning device 80 and the related pellicle 82, reference is made to, for instance, US10466585B2 or US2019025717A1.

[00034] The illumination system IL is configured to condition the EUV radiation beam B before the EUV radiation beam B is incident upon the patterning device MA. Thereto, the illumination system IL may include a faceted field mirror device 10 and a faceted pupil mirror device 11. The faceted field mirror device 10 and faceted pupil mirror device 11 together provide the EUV radiation beam B with a desired cross-sectional shape and a desired intensity distribution. The illumination system IL may include other mirrors or devices in addition to, or instead of, the faceted field mirror device 10 and faceted pupil mirror device 11.

[00035] After being thus conditioned, the EUV radiation beam B interacts with the patterning device MA. As a result of this interaction, a patterned EUV radiation beam B' is generated. The projection system PS is configured to project the patterned EUV radiation beam B' onto the substrate W. For that purpose, the projection system PS may comprise a plurality of mirrors 13, 14 which are configured to project the patterned EUV radiation beam B' onto the substrate W held by the substrate table WT. The projection system PS may apply a reduction factor to the patterned EUV radiation beam B', thus forming an image with features that are smaller than corresponding features on the patterning device MA. For example, a reduction factor of 4 or 8 may be applied. Although the projection system PS is illustrated as having only two mirrors 13, 14 in Figure 1, the projection system PS may include a different number of mirrors (e.g., six or eight mirrors).

[00036] The substrate W may include previously formed patterns. Where this is the case, the lithographic apparatus LA aligns the image, formed by the patterned EUV radiation beam B', with a pattern previously formed on the substrate W.

[00037] A relative vacuum, i.e. a small amount of gas (e.g. hydrogen) at a pressure well below atmospheric pressure, may be provided in the radiation source SO, in the illumination system IL, and/or in the projection system PS. The pressure well below atmospheric pressure may be in the order of 5 Pa.

[00038] The radiation source SO shown in Figure 1 is, for example, of a type which may be referred to as a laser produced plasma (LPP) source. A laser system 1, which may, for example, include a CO₂

laser, is arranged to deposit energy via a laser beam 2 into a fuel, such as tin (Sn) which is provided from, e.g., a fuel emitter 3. Although tin is referred to in the following description, any suitable fuel may be used. The fuel may, for example, be in liquid form, and may, for example, be a metal or alloy. The fuel emitter 3 may comprise a nozzle configured to direct tin, e.g. in the form of droplets, along a trajectory towards a plasma formation region 4. The laser beam 2 is incident upon the tin at the plasma formation region 4. The deposition of laser energy into the tin creates a tin plasma 7 at the plasma formation region 4. Radiation, including EUV radiation, is emitted from the plasma 7 during de-excitation and recombination of electrons with ions of the plasma.

[00039] The EUV radiation from the plasma is collected and focused by a collector 5. Collector 5 comprises, for example, a near-normal incidence radiation collector 5 (sometimes referred to more generally as a normal-incidence radiation collector). The collector 5 may have a multilayer mirror structure which is arranged to reflect EUV radiation (e.g., EUV radiation having a desired wavelength such as 13.5 nm). The collector 5 may have an ellipsoidal configuration, having two focal points. A first one of the focal points may be at the plasma formation region 4, and a second one of the focal points may be at an intermediate focus 6, as discussed below.

[00040] The laser system 1 may be spatially separated from the radiation source SO. Where this is the case, the laser beam 2 may be passed from the laser system 1 to the radiation source SO with the aid of a beam delivery system (not shown) comprising, for example, suitable directing mirrors and/or a beam expander, and/or other optics. The laser system 1, the radiation source SO and the beam delivery system may together be considered to be a radiation system.

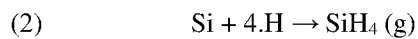
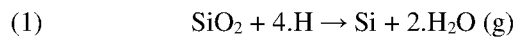
[00041] Radiation that is reflected by the collector 5 forms the EUV radiation beam B. The EUV radiation beam B is focused at intermediate focus 6 to form an image at the intermediate focus 6 of the plasma present at the plasma formation region 4. The image at the intermediate focus 6 acts as a virtual radiation source for the illumination system IL. The radiation source SO is arranged such that the intermediate focus 6 is located at or near to an opening 8 in an enclosing structure 9 of the radiation source SO.

[00042] Although Figure 1 depicts the radiation source SO as a laser produced plasma (LPP) source, any suitable source such as a discharge produced plasma (DPP) source or a free electron laser (FEL) may be used to generate EUV radiation.

[00043] The dose of radiation that is provided to the substrate is an important consideration when performing a lithographic exposure. The dose of radiation reaching the substrate W may vary over time due to unwanted absorption of EUV radiation. For example, surfaces within the lithographic apparatus may release one or more chemicals (for instance silanes) into an internal environment of the lithographic apparatus. The presence of said chemicals may reduce a transmission of EUV radiation through the internal environment of the lithographic apparatus, thus reducing the dose of radiation provided to the substrate.

[00044] During operation of an EUV scanner, hydrogen gas introduced in the scanner optics section may be ionized, providing hydrogen plasma. Upon impact of hydrogen ions, Silicon and Silicon-rich surfaces (including oxidized silicon, such as SiO₂) have a tendency to form volatile SiH₄ and thus to lose silicon from the surface. In case of the pellicle 80, this results in changing pellicle transmission (and thus dose errors), limits lifetime of the reticle, and may give Si-deposition on the EUV mirrors.

[00045] In practice, any surfaces comprising silicon are typically at least partly oxidized. As a result, the chemical reaction includes two steps, as indicated below. Reaction (1) is expected to be rate-limiting:



[00046] In order to mitigate the reduced transmission of EUV radiation, a gas may be introduced to the lithographic apparatus. The gas may be an oxygen containing gas, for instance comprising one or more of oxygen (O₂), water (H₂O), and hydrogen peroxide (H₂O₂). The lithographic apparatus may, for example, be an extreme ultraviolet (EUV) lithographic apparatus. The system and method of the present disclosure enable to provide a controlled amount of gas to an apparatus such as a lithographic apparatus.

[00047] One method of accurately controlling the relatively small amount of oxygen containing gas that is to be provided to the lithographic apparatus includes mixing a first gas comprising the oxygen containing gas (O₂) with one or more other gases. The one or more other gases lack an oxygen containing gas. The gases are mixed before introducing a controlled flow of the mixture of gases to the lithographic apparatus. For example, clean dry air, CD A, (for instance extreme clean dry air, XCDA) may be mixed with a gas such as nitrogen gas (N₂) or hydrogen gas (H₂) so as to dilute the amount of oxygen containing gas in the clean dry air to a lower concentration. The mixture of gases may be such that it comprises a suitably low concentration of oxygen containing gas, suitable for use in a lithographic apparatus.

[00048] Referring to Figure 1, the lithographic apparatus LA includes at least one system 100 to provide a flow of gas to selected parts of the apparatus LA. The at least one system 100 comprises a first gas source 110 for providing a flow 120 of the oxygen containing gas. The system 100 comprises a second gas source 112 for providing a second gas flow 130 of a gas lacking oxygen, for instance nitrogen gas or hydrogen gas. The gas flows 120 and 130 are combined and mixed to form a gaseous mixture 160.

[00049] The at least one system 100 may include, for instance, one or more suitable conduits. See Figure 2 for an example. The flow may be provided at or near one or more mirrors as indicated in Figure 1, for instance faceted field mirror device 10 and faceted pupil mirror device 11, or mirrors 13, 14. The mixture 160 may be introduced via one or more gas inlets 116, 118, 222 (Fig. 1). Thus, the mixing

of gases enables the provision of low partial pressures of oxygen containing gas proximate one or more optical components of the lithographic apparatus with suitable accuracy and stability.

[00050] The lithographic apparatus LA may be provided with one or more outlets 224 to purge gas. The outlet 224 may be connected to one or more low pressure devices 226 via respective conduits 228.

5 The low pressure device 226 may comprise one or more of a pump, vacuum chamber, and filters and membranes to clean the gas purged from the apparatus LA.

[00051] The outlet 224 may be positioned at a location of choice. For the system and method of the disclosure, at least one outlet 224 and related exhaust conduit 228 may be connected to the reticle mini environment RME. The latter allows dedicated control of the gas mixture in the RME, obviating
10 interference of the gas mixture with the sensitive optics sections IL and PS.

[00052] As exemplified in Figure 1, alternatively or in addition, at least one outlet 224 may be connected to the projection system PS. The outlet 224 in the RME and the PS allow a suitable pressure differential between the respective inlets and outlets. This also allows a suitable pressure differential between the reticle mini environment RME and the projection system PS.

15 [00053] Figure 2 shows an example of an embodiment of the at least one gas flow control system 100. The system 100 may comprise a first mass flow controller 140 to control the flow 120. A second mass flow controller 150 may control the flow 130 of the non-oxygen containing gas, typically hydrogen gas. A pressure gauge and/or pressure controller 170 may be provided to monitor and/or control a pressure of the gaseous mixture 160. The gaseous mixture 160 may be split over one or more
20 conduits or branches 180.1, 180.2, 180.3. A first conduit 180.1 may comprise a valve 190 and may be connected to a dump 200. The valve 190 may be configured to control the flow of the gaseous mixture through the first branch 180.1. The dump 200 may be configured to receive any excess gaseous mixture that is not needed in an internal environment 210 of the lithographic apparatus.

[00054] The second conduit 180.2 and/or third conduit 180.3 may comprise a mass flow controller
25 220, 230 and/or a valve 240, 250. The second conduit 180.2 and third conduit 180.3 may be configured to supply a controlled amount of the gaseous mixture 160 to different parts of the internal environment 210 of the lithographic apparatus. For example, the second branch 180.2 may provide a flow of the gaseous mixture 160 proximate the reticle MA. The third branch 180.3 may provide a flow of the gaseous mixture 160 proximate the substrate W.

30 [00055] The mixture of gases 160 may be distributed amongst one or more desired locations within the lithographic apparatus. See Figures 1 and 3 for a schematic overview. The mixture of gases may be introduced to the litho apparatus via one or more gas inlets 116, 118, 222. The oxygen containing gas may be provided via one or more membranes 114, as shown in Figure 1. Alternatively or additionally, the gas may be provided using mass flow controllers, as exemplified in Figure 2.

35 [00056] Figure 3 shows a schematic overview of another embodiment indicating respective conduits 180.1, 180.2 connecting the first gas source 110 and second gas source 112 to various sections of the

lithographic apparatus LA, such as the reticle mini-environment RME, the projection system PS, and the illumination system IL.

[00057] Generally referring to Figure 4, in an embodiment, at least one inlet 116 is connected to the reticle mini-environment. The inlet 116 may include itself include a multitube of inlets connecting the gas flow to the RME and directing the gas flow towards a target area of choice, typically the mask assembly MA. The inlet 116, which may be referred to as Y-Nozzle or Q_{ynoz} , directs the mixture 160 along the reticle 80 and the pellicle 82. At least part of the gas flow 160 will flow between the reticle 80 and the pellicle 82. The RME may be provided with at least one outlet 117 allowing to remove gas from the RME.

[00058] In an embodiment, the reticle mini-environment RME may be connected to a cone shaped element 270. The element 270 may have an opening 272 connecting to the illumination optics IL and the projection system PS. In a practical embodiment, the opening 272 of the cone 270 is connected to the openings 70, 72 as shown in Figure 1.

[00059] A slightly higher pressure in the RME with respect to the PS allows a gas flow from the RME towards to projection system, preventing contaminants to reach the mask assembly MA. A pressure rating within the RME and PS may be in the order of 5 Pa. Generally referring to Figure 4, a pressure differential between the inlet 116 and the outlet 117 in the RME may, in a practical embodiment, be in the order of 0.05 to 0.5 Pa, allowing a gas flow along the mask assembly MA. The latter has the advantage of preventing the gas mixture in the RME from interfering with the sensitive optics environment IL and PS.

[00060] In a practical embodiment, the present disclosure proposes to add a trace amount of hydrogen peroxide (H_2O_2) to the local H_2 flow as an oxidizing fraction. Even a trace amount of H_2O_2 will shift the equilibrium of the reaction (1) referenced above to keep the surface layer of respective silicon comprising components oxidized.

[00061] In a practical embodiment, the non-oxygen comprising gas is typically hydrogen. For instance, the mixture 160 comprises more than 90 mol%, or more than 95 mol%, more than 99 mol%, or more than 99.9 mol% of the non-oxygen containing gas. The non-oxygen containing gas is typically H_2 . The mixture 160 typically has a relatively low concentration of oxygen containing gas. Relatively low herein may refer to a percentage (mol%) in the order of 5% or below, for instance in the range of 0.01 to 1 mol%. For instance, the mixture 160 may comprise oxygen containing gas in the range of 10 to 500 ppm, for instance 10 to 250 ppm, for instance about 10 to 100 ppm.

[00062] H_2O_2 is a preferred oxidant, for instance over O_2 and H_2O , since the oxidation is self-limiting to the top surface layer. In operation, the H_2O_2 splits in 2.OH which results in high surface coverage of OH to prevent adsorption of further H_2O_2 molecules, and low permeation. On the other hand, H_2O splits in OH and H, and as a result provides lower adsorption site protection, and O_2 splits in 2.O, which has relatively high permeation. O_2 is difficult to add in trace amounts to hydrogen, and the resulting mixture of hydrogen and oxygen has safety concerns, as the mixture may be explosive. In

addition, O_2 and H_2O are not (or less) self-limiting than H_2O_2 , so have a tendency to oxidize more than just the top surface layer. Self-limiting herein relates, for instance, to the formulas (1) and (2) above, wherein formula (1) is self-limiting, i.e. the reaction rate of formula (1) limits the reaction rate of formula (2).

5 [00063] In an embodiment, the oxygen containing gas, typically H_2O_2 , is added via a membrane 114. See Figure 1 for examples of a practical embodiment. Hydrogen (H_2) flows over the membrane, with a solvent containing H_2O_2 on the other side (see attachment for more details). Dosing of H_2O_2 can be accurately controlled by flow speed of the H_2 over the membrane and the effective membrane area. This in turn allows the trace amounts of H_2O_2 to be added in a sufficient yet constant relative amount,
10 i.e. relative to the second gas from the second source 112. The respective amounts of H_2O_2 are exemplified above.

[00064] The membrane may comprise a suitable material, for instance a perfluoropolymer. Using addition via membrane enables a fluid-based H_2O_2 source (in reservoir 110) to provide a stable influx of H_2O_2 into the H_2 flow without waste.

15 [00065] Industrialized hydrogen peroxide membrane solutions suitable for the present disclosure are, for instance, available from RASIRC [San Diego, CA, USA], for instance RASIRC's Nafion® membrane.

[00066] The embodiments of the present disclosure provide the following advantages: i) Stable transmission of the silicon based pellicle 82 over time; ii) Longer pellicle lifetime due to reduced pellicle
20 material loss; and iii) reduced Silicon outgassing risk to mirrors.

[00067] 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-
25 crystal displays (LCDs), thin-film magnetic heads, etc.

[00068] Although specific reference may be made in this text to embodiments of the invention in the context of a lithographic apparatus, embodiments of the invention may be used in other apparatus. Embodiments of the invention may form part of a mask inspection apparatus, a metrology apparatus, or any apparatus that measures or processes an object such as a wafer (or other substrate) or mask (or
30 other patterning device). These apparatus may be generally referred to as lithographic tools. Such a lithographic tool may use vacuum conditions or ambient (non-vacuum) conditions.

[00069] Although specific reference may have been made above to the use of embodiments of the invention in the context of optical lithography, it will be appreciated that the invention, where the context allows, is not limited to optical lithography and may be used in other applications, for example
35 imprint lithography.

[00070] 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 method for preventing degradation of a material of an optical component for extreme ultraviolet light (EUV) lithography, the method comprising the steps of:
- 5 - arranging a wafer on a wafer table;
- producing extreme ultraviolet light using a source of extreme ultraviolet light;
- reflecting the extreme ultraviolet light towards the wafer via at least one reflective device, the at least one reflective device including a reticle device for providing a pattern to the extreme ultraviolet light; and
- 10 - stabilizing a material of the at least one reflective device by providing an oxygen containing gas.
2. The method of claim 1, wherein the oxygen containing gas comprises hydrogen peroxide (H₂O₂).
- 15 3. The method of claim 1 or 2, wherein the material comprises silicon.
4. The method of one of claims 1 to 3, wherein the reticle device comprises a reticle provided with a pellicle arranged in parallel to the reticle,
wherein the reticle device is arranged in a reticle mini-environment, the step of stabilizing the material
20 at least comprising providing the oxygen containing gas to the reticle mini-environment.
5. The method of claim 4, wherein providing the oxygen containing gas to the reticle mini-environment comprises flowing the oxygen containing gas along the pellicle.
- 25 6. The method of one of claims 1 to 5, the step of providing an oxygen containing gas comprising:
- providing a flow of hydrogen containing gas;
- adding the oxygen containing gas to the flow of hydrogen.
- 30 7. The method of claim 6, the step of adding the oxygen containing gas to the flow of hydrogen comprising:
- providing a source of the oxygen containing gas, the source having an outlet provided with a membrane;
- contacting the flow of hydrogen containing gas with an outer surface of the membrane.
- 35 8. The method of claim 7, the step of adding the oxygen containing gas to the flow of hydrogen comprising the step of:

- controlling the amount of oxygen containing gas added to the flow of hydrogen by adjusting the flow rate of the hydrogen as a function of said outer surface of the membrane.

5 9. An assembly for preventing degradation of a material of an optical component for extreme ultraviolet light (EUV) lithography, the assembly comprising:

- at least one optical component for reflecting the extreme ultraviolet light arranged in a vacuum chamber; and
- the vacuum chamber having at least one inlet for gas adapted to provide an oxygen containing gas to the at least one reflective device, and an outlet for the gas.

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10. The assembly of claim 9, wherein the at least one reflective device includes a reticle device for providing a pattern to the extreme ultraviolet light, the reticle device comprising a reticle provided with a pellicle arranged in parallel to the reticle, at least one inlet for gas being adapted to direct a flow of the oxygen containing gas along the pellicle.

15

11. The system of claim 9 or 10, wherein the oxygen containing gas comprises hydrogen peroxide (H₂O₂).

12. The system of claim 9, 10 or 11, wherein the material comprises silicon.

20

13. The system of one of claims 9 to 12, comprising:

- at least one conduit connecting a source of hydrogen containing gas to the at least one inlet for gas;
- a source of the oxygen containing gas, having an outlet provided with a membrane, an outer surface of the membrane being exposed to the at least one conduit.

25

14. A lithographic system being adapted for the method of claim 1 or comprising the assembly of claim 9.

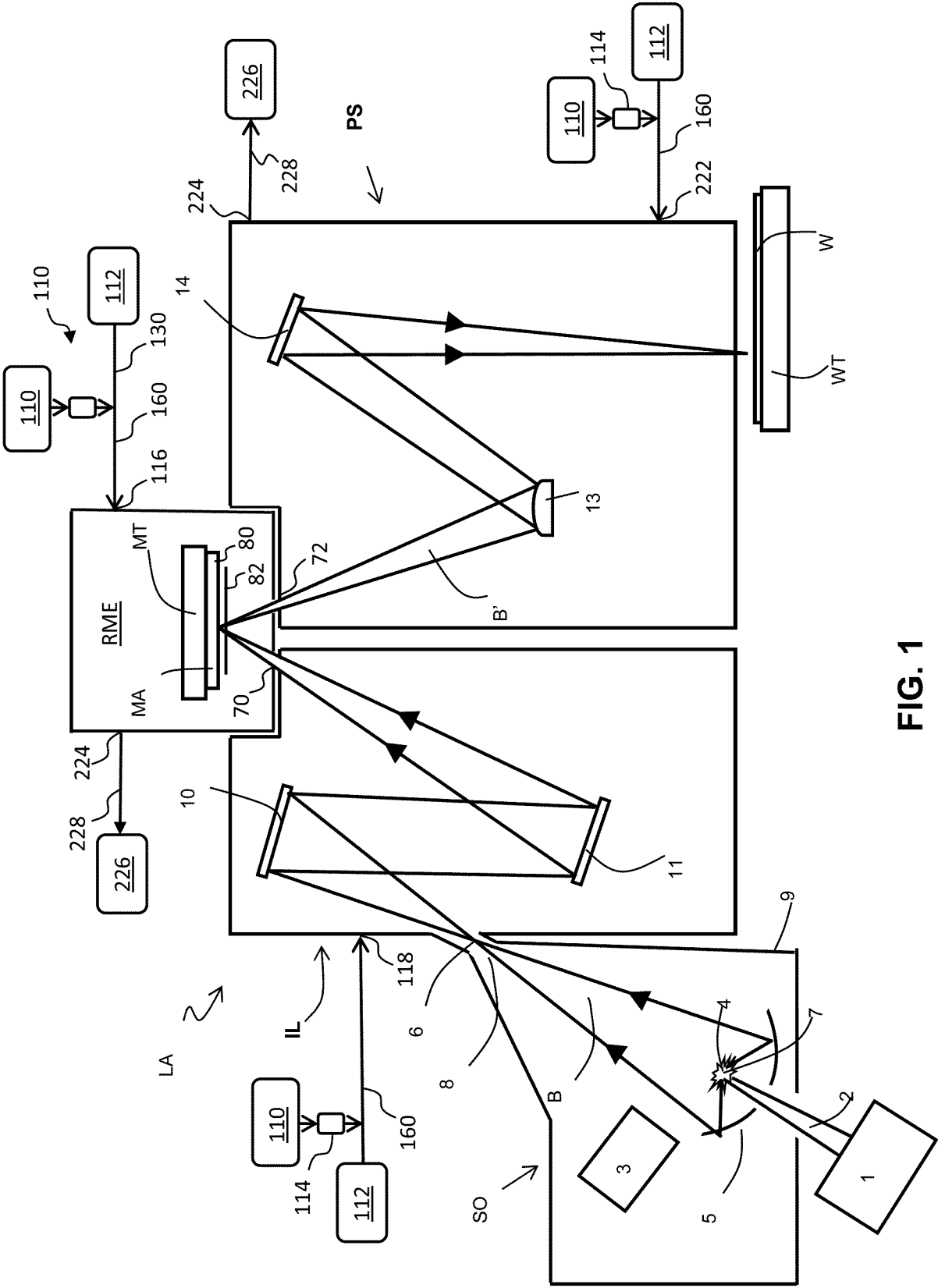


FIG. 1

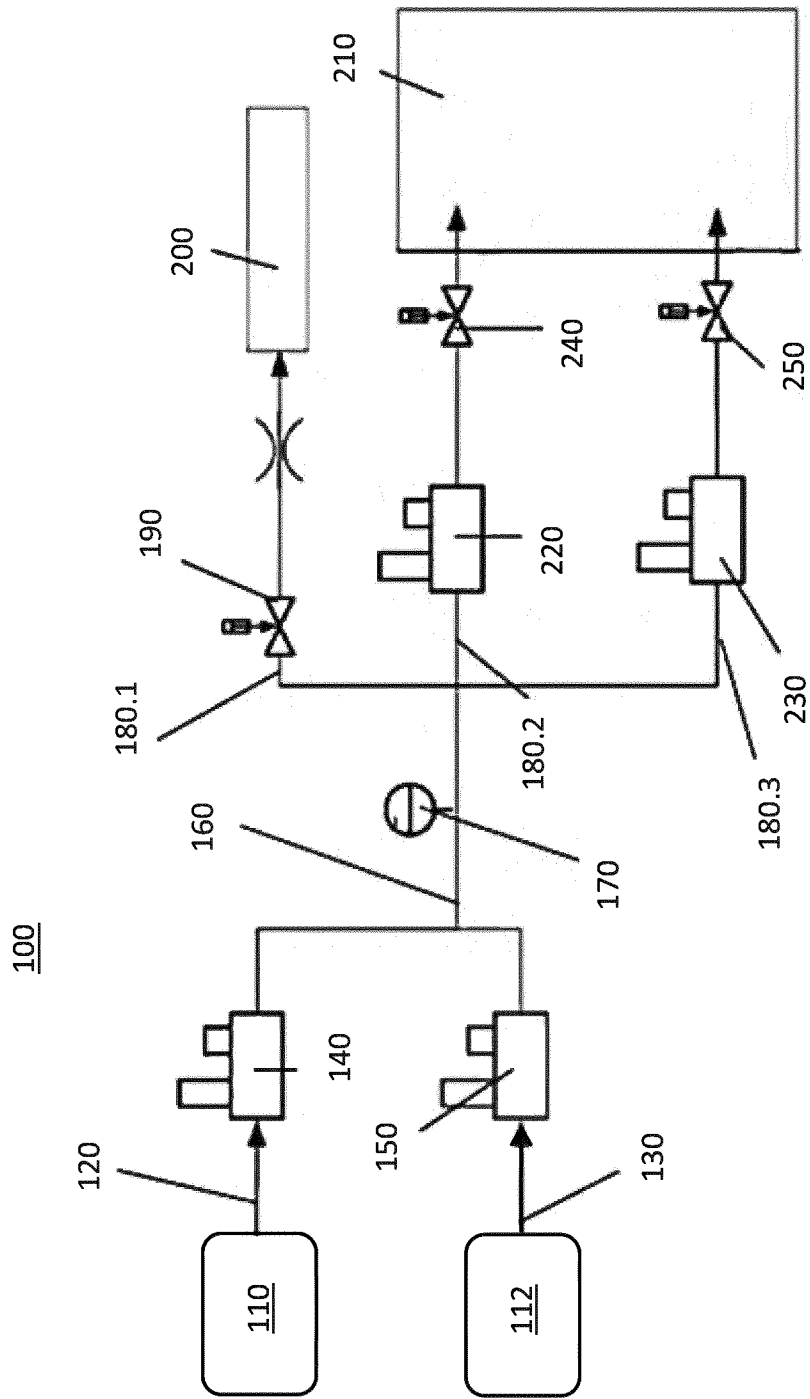
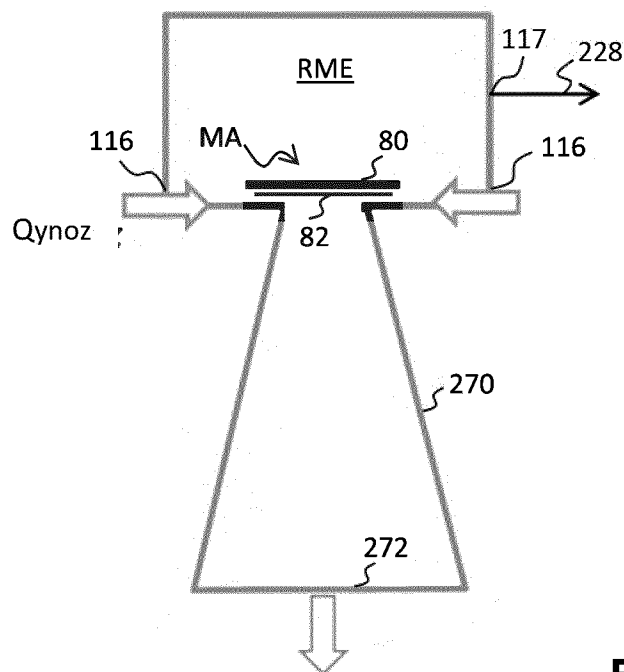
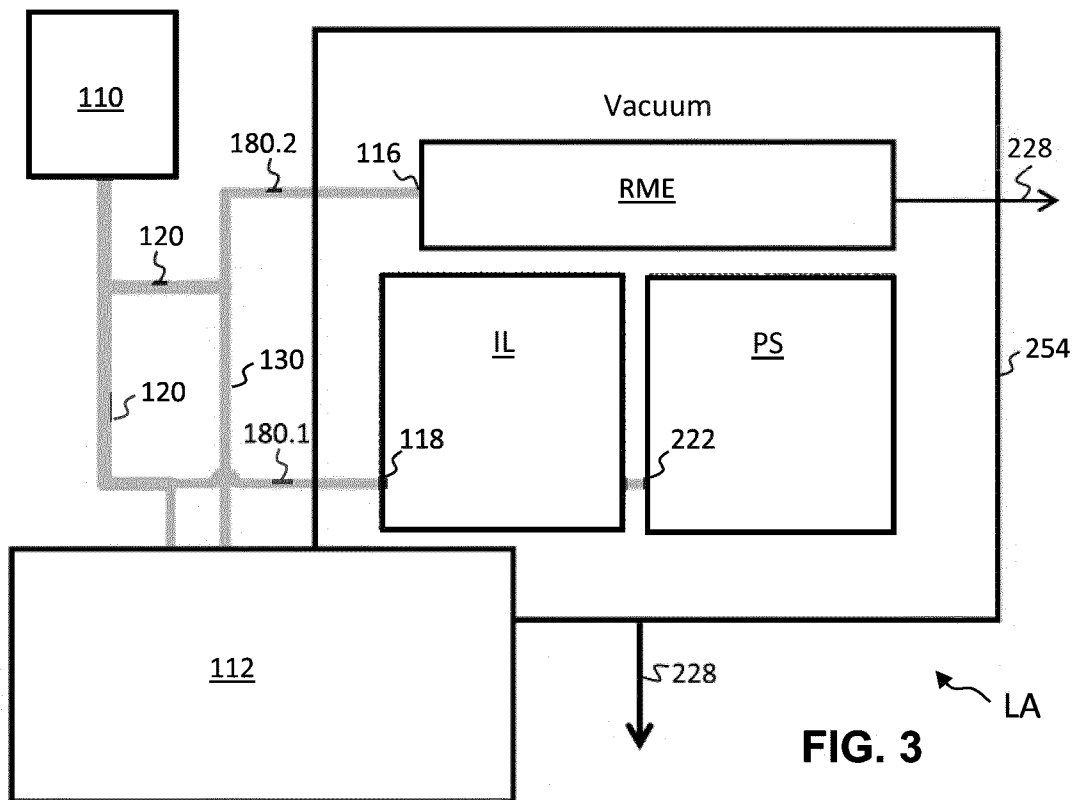


FIG. 2



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2022/082711

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)
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	US 2020/183292 A1 (BECKER MORITZ [DE] ET AL) 11 June 2020 (2020-06-11)	1-6, 14
A	abstract figures 1, 5 paragraphs [0002], [0019], [0020], [0052], [0093] - [0123] -----	7-13
X	US 2017/212433 A1 (EHM DIRK HEINRICH [DE] ET AL) 27 July 2017 (2017-07-27)	9-12, 14
A	abstract figure 1 paragraphs [0002], [0009], [0014], [0035], [0048] - [0058] ----- -/-	1-8, 13

☒ 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

6 March 2023

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15/03/2023

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INTERNATIONAL SEARCH REPORT

International application No

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2021/109452 A1 (MA YUE [US] ET AL) 15 April 2021 (2021-04-15) abstract figure 1 paragraphs [0062] - [0064] -----	1-14
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International application No

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