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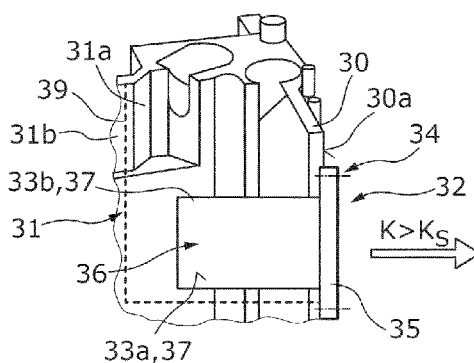


Fig. 3

(57) Abstract: The invention relates to an optical arrangement for EUV lithography, comprising: a housing (30), at least one optical element disposed within an interior (31) of the housing (30), and at least one gas-binding component (32) having at least one surface (33a, 33b) with a gas-binding material for binding of gaseous contaminating substances present in the interior (31). The gas-binding component (32) is secured to the housing (30) via a connection (34) which can be disconnected from an outer face (30a) of the housing (30) in order to remove the gas-binding component (32) from the housing (30). The invention also relates to a method of regenerating at least one gas-binding component (32) of the above-described optical arrangement, comprising: disconnecting (34) the gas-binding component (32) from the housing (30), removing the gas-binding component (32) from the optical arrangement, and regenerating the gas-binding material by heating the surface (33a, 33b) with the gas-binding material.

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Optical arrangement for EUV lithography and method of regenerating a gas-binding component

Cross-Reference to Related Application

This application claims priority to German Patent Application 102021205985.6 filed June 11, 2021, the entire disclosure of which is considered part of and is incorporated by reference in the disclosure of this application.

Background of the invention

The invention relates to an optical arrangement for EUV lithography, comprising: a housing, at least one optical element disposed within an interior of the housing, and at least one gas-binding component having at least one surface with a gas-binding material for binding of gaseous contaminating substances present in the interior. The invention also relates to a method of regenerating at least one gas-binding component of such an optical arrangement.

In the context of this application, an optical arrangement for EUV lithography is understood to mean an optical arrangement that can be used in the field of EUV lithography. As well as a projection exposure system for EUV lithography which serves for production of semiconductor components, the optical arrangement may, for example, be an inspection system for inspection of a photomask used in such a projection exposure system (also referred to hereinafter as reticle), for inspection of a semiconductor substrate to be structured (also referred to hereinafter as a wafer) or a metrology system which is used for measurement of

a projection exposure system for EUV lithography or parts thereof, for example for measurement of a projection optical unit.

Very high cleanliness demands are applicable to optical arrangements for EUV lithography and the components thereof. As well as particle contamination and the absence of organic contaminants, the surface coverage of the optical surfaces of mirrors with hydrogen-volatile elements, called the HIO elements (= hydrogen-induced outgassing), for example phosphorus-, zinc-, tin-, sulfur-, indium-, magnesium- or silicon-containing compounds, is specified, since the presence thereof on the optical surfaces, possibly in conjunction with oxidation, adversely affects the transmittance of the optical arrangement.

In the context of analyses, it was found that one possible cause of the mirror contamination lies in the coverage of surfaces of the mechanical (i.e. non-optical) components installed in the proximity of the mirror with contaminants including HIO elements or compounds that are redistributed from the surfaces of these components onto the surfaces of the mirrors under operating conditions.

It is known that it is possible to dispose gas-binding components in such an optical arrangement that have at least one surface of a gas-binding material, in order to bind the contaminating substances, especially the HIO compounds, and in this way to avoid accumulation on the surfaces of the mirrors.

US 7473908B2 discloses a lithography system comprising an object having a first surface designed to bind metallic contaminations, e.g. metals, metal oxides, metal hydroxides, metal hydrides, metal halides and/or metal oxyhalides of the elements Sn, Mn and/or Zn. The first surface may have a metallic surface, with the metal selected from the group comprising: Ru, Rh, Pd, Ag, Re, Os, Ir, Pt and/or Au.

US 8,382,301 B2 describes a projection exposure system for EUV lithography. This has a housing with at least one optical element disposed therein. Also disposed within the housing is at least one vacuum housing that surrounds at least the optical surface of the optical element. In one example, the vacuum housing serves as contamination reduction unit and consists of a gas-binding material on its inner face at least in one subregion. The contamination reduction unit may also have a cooling unit that cools the vacuum housing down to temperatures of less than 80 K, for example. In this way, the inner face of the vacuum housing forms a cryo-panel in order to bind contaminating substances on the surface of the vacuum housing.

DE 10 2014 204 658 A1 describes an optical arrangement having a casing with at least one component disposed therein that outgases contaminating substances on contact with activated hydrogen. An opening duct connects the component to a vacuum chamber with at least one optical element disposed therein. The inner wall of the opening duct may have a coating for reduction of the exit rate of the contaminating substances that contains a material selected from the group comprising: Rh, Ru, Ir, Pt, Ti, Ni, Pd and compounds thereof. For reduction of the entry rate of the activated hydrogen, the coating may contain a material selected from the group comprising: Rh, Ru, Ir, Pt, Ti, Ni, Pd, Al, Cu, Fe and compounds thereof.

US 2020/0166847 A1 describes an optical arrangement for EUV lithography which comprises at least one reflective optical element having a main body with a coating that reflects EUV radiation. At least one shield is fitted to at least one surface region of the main body and protects the surface region against any etching effect of a plasma surrounding the reflective optical element during operation of the optical arrangement. The material of the shield may be selected from the group comprising: metallic materials, especially Cu, Co, Pt, Ir, Pd, Ru, Al, stainless steel, and ceramic materials, especially AlO_x , Al_2O_3 . The shield or cover may consist of a hydrogen recombination material or include a hydrogen

recombination material. The hydrogen recombination material may serve as contamination getter material, for example when it is selected from the group comprising: Ir, Ru, Pt, Pd.

When a gas-binding material is used for binding of the contaminating substances, there is the problem that the gas-binding action of the gas-binding material decreases as the amount of contaminating substances bound by the gas-binding material at the surface increases.

Object of the invention

It is an object of the invention to provide an optical arrangement for EUV lithography that enables counteracting of a loss of transmittance over a maximum period of time.

Subject matter of the invention

This object is achieved by an optical arrangement of the type specified at the outset, in which the gas-binding component is secured to the housing by a connection which is disconnectable from an outer face of the housing in order to remove the gas-binding component from the housing (and typically also from the optical arrangement).

What is proposed in accordance with the invention is securing of the gas-binding component having the at least one surface with the gas-binding material to the housing via a disconnectable connection. The disconnectable connection may be disconnected from the outer face of the housing manually by a user or in an automated manner. After the connection has been disconnected, the component can be removed from the housing or from the optical arrangement. For the removal, the housing has an opening through which the gas-binding component, or more specifically a section of the gas-binding component that

projects into the interior of the housing, can be removed from the housing. The gas-binding component(s) is/are preferably secured to sites on the housing that are readily accessible from the exterior.

Typically, the components having a surface with a gas-binding material (getter surface) are installed in a fixed manner in the optical arrangement or can be exchanged only in the case of complete disassembly of the optical arrangement in which the housing is taken apart. Such an exchange may be required on account of decreasing transmittance of the optical arrangement even if the optical arrangement would otherwise still be capable of working, and is associated with a considerable degree of cost and inconvenience.

In the optical arrangement described further up, exchange of the gas-binding components having the getter surface(s) on which there are accumulated contaminating substances for new components with gas-binding material on which there are still no accumulated contaminating substances is possible without having to disassemble the housing for that purpose. It may also be possible to remove the gas-binding component from the housing or from the optical arrangement without having, for that purpose, to break the vacuum that typically exists in the interior, wherein the optical element is disposed, during the operation of the optical arrangement. In this way, it is possible to counteract any loss of transmittance of the optical arrangement over a long period of time, especially over the entire lifetime of the optical arrangement, without having to disassemble the optical arrangement.

The housing on which the at least one gas-binding component is secured in a disconnectable manner may be a housing accessible directly from the outside, i.e. from the environment of the optical arrangement. It may alternatively be a housing surrounded by another, larger housing of the optical arrangement. For example, the housing may be that of a projection optical unit, of an exposure optical unit, or of a radiation source of an EUV lithography system. Alternatively,

it is possible that the housing surrounds the projection optical unit, the exposure optical unit and the radiation source. The optical element disposed in the interior of the housing may optionally be disposed in a (further) vacuum housing within the interior of the housing (mini-environment), as described in US 8,382,301 B2 cited at the outset, which is incorporated in its entirety into this application by reference.

In one embodiment, the gas-binding component has a securing section for disconnectable securing on an outer face of the housing. The securing section may, for example, be designed as a kind of flange that is brought into two-dimensional contact with the outer face of the housing. If the connection of the securing section to the housing is disconnected, the component can be removed through an opening in the housing. It will be apparent that the component has a geometry that enables said component, or more specifically a section that projects into the interior of the housing, to be removed from the housing via the opening. The securing section has a greater extent than the opening in the housing, in order to cover the opening and to seal the housing in a gas-tight manner. The residual gas-binding component, i.e. the section that projects into the interior, has a cross section which is less than the cross section of the opening, in order to enable the removal of the component from the housing.

In one development of this embodiment, the securing section is secured to the outer face of the housing via a disconnectable connection in the form of a screw connection. The screw connection is a connection which is particularly easy and quick to disconnect and enables gas-tight securing of the gas-binding component, or more specifically the securing section, to the housing.

In a further embodiment, the gas-binding material is applied to the (at least one) surface in the form of a coating. Such a coating may be applied to the surface, for example, by means of a conventional method of depositing material from the

gas phase. The gas-binding material enables the binding of the contaminating substances, since these enter into chemically stable compounds having an immeasurably low vapor pressure with the gas-binding material. The surface material to which the coating is applied may, for example, be a metallic material, for example steel. Alternatively, the gas-binding material may be a solid body composed of a typically metallic material with no coating applied to the surface thereof.

The gas-binding material is preferably selected from the group comprising: Ta, Nb, Ti, Zr, Th, Ni, Ru. Additionally or alternatively to the materials mentioned, it is also possible to use other materials with a gas-binding function.

The gas-binding material used is generally a metal or an alloy that binds the contaminating substances by absorption, chemisorption or chemical reaction. The gas particles of the contaminating substances adsorbed on the surface of the gas-binding material diffuse rapidly into the interior of the gas-binding material and make room for further gas particles that hit the surface. The abovementioned materials and any further materials enable binding of the contaminating substances or a majority of types thereof, for example in the form of Si, Mg, etc., that are present in the optical arrangement for EUV lithography, more specifically in the interior thereof.

In a further embodiment, the gas-binding component has at least one plate section, on which the at least one surface having the gas-binding material is formed. The plate section may, for example, be a metal sheet (in plate form), a metal sheet in the form of a strip or the like, which is connected to the securing section or is formed in one piece therewith. A plate section is understood to mean that the section has a comparatively low thickness compared to the length and width of the section. The plate section may be in planar or curved or angled form.

The plate section of the gas-binding component runs within the interior of the housing of the optical arrangement outside the optical beam path. The geometry or shape of the plate section may be matched to the shape of a region or component to be covered in the interior of the housing. The plate section may serve, for example, for coverage of large aluminum structure components. It is advantageous to provide a maximum surface area for uptake of the contaminating substances with respect to the surface area of the component to be covered which is of relevance for the outgassing of contaminating substances. The greater the area of the plate section, in general, the more effective the gas-binding action of the gas-binding component.

The plate sections of the gas-binding components may be arranged at a small distance from the respective structure or structure wall to be covered or else freely in space – taking account of the optical beam path. One and the same gas-binding component may also have two or more plate sections mounted on one and the same securing section in order to increase the surface area available for the binding of the contaminating substances. The two or more sections may, for example, be in a laterally offset arrangement with respect to one another and form a multiple baffle. Alternatively, another type of arrangement of the plate sections is possible.

In one development of this embodiment, the plate section has a first surface with a gas-binding material and a second surface, opposite the first, with a gas-binding material. In this case, the two opposite sides or surfaces of the plate section are covered with the gas-binding material. It is possible that one and the same gas-binding material is present on both surfaces, or that the two surfaces have different gas-binding materials in order to bind different types of contaminating substances. It has been found that it is favorable when not only the surface of the plate section facing a component that outgases contaminating substances but also the surface remote from such a component has a gas-binding material. The provision of the gas-binding material on both sides of the

plate section increases the surface area available for the binding of the contaminating substances.

In a further embodiment, the optical arrangement has at least one cooling device for cooling of the surface having the gas-binding material. The cooling device, for example in the form of a Peltier element, enables the cooling of the surface of the component on which the gas-binding material is present. For this purpose, for example, the gas-binding component may incorporate at least one cooling duct through which a cooling fluid flows or within which a cooled wire or the like runs. The cooling of the gas-binding component or of the surface with the gas-binding material allows the contaminating substances to be "frozen out". For this purpose, the gas-binding component(s) is/are cooled at least during the operation of the optical arrangement and optionally additionally during the breaks in operation. Prior to the deinstallation of the respective gas-binding component from the housing or from the optical arrangement, the cooling device is typically deactivated.

In a further embodiment, the optical arrangement comprises at least one vacuum lock for severing a connection of a part-volume of the interior of the housing in which the surface with the gas-binding material is disposed from the remaining interior of the housing, or for separating a sub-volume of the environment of the housing in which the securing section is disconnectably secured on the outer face of the housing from the rest of the environment of the housing. In the former case, the closing of the vacuum lock can result in flooding of the sub-volume having the gas-binding surface or having the section of the gas-binding component that projects into the interior, such that this can be removed from the housing, without having to break the vacuum in the remainder of the interior for that purpose. In this way, it is possible to maintain exposure operation during the removal or exchange of the gas-binding component. Alternatively, it is possible to connect a vacuum lock that surrounds the securing section of the gas-binding component to the outside of the

housing. In this case, the gas-binding component is disconnected from the housing within the vacuum lock and exchanged for another gas-binding component, the gas-binding material of which has higher gas-binding action. In this way too, it is possible to avoid breaking of the vacuum in the interior.

Alternatively, for the removal or for the exchange of the gas-binding component, the vacuum in the interior can be broken. In this case, the removal can in particular be effected when the breaking of the vacuum is required in any case for some other reason, for example if maintenance of the optical arrangement is being conducted. In this case, it is favorable when the gas-binding component can be removed rapidly from the housing and exchanged for a new gas-binding component. It is especially favorable when, in this case, a reservoir of new or regenerated (see below) gas-binding components is available in order to replace the gas-binding component to be exchanged with a new gas-binding component immediately after withdrawal from the optical arrangement, in order to enable rapid recommissioning and avoid shutdown time.

A further aspect of the invention relates to a method of regenerating at least one gas-binding component of the optical arrangement described further up, comprising: disconnecting the gas-binding component from the housing, removing the gas-binding component from the optical arrangement, and regenerating the gas-binding material by heating the surface with the gas-binding material.

The inventors have recognized that regeneration of the gas-binding material, for example by heating of the gas-binding component, in which the bound contaminating substances are transferred to the gas phase, is not directly possible *in situ*, i.e. within the housing or the optical arrangement, since the contaminating substances here have to be released again and pumped out of the interior of the housing. The pumping powers and pumping times that are required for this purpose are considerable, and so such a regeneration of the

gas-binding material or of the corresponding surfaces *in situ* is not a realistic aim. This problem does not exist when the gas-binding component(s) is/are removed from the housing or from the optical arrangement for the regeneration.

The regeneration exploits the fact that the gas-binding material can be regenerated to a certain degree by heating, as is known from what are called getter pumps. For the heating of the surface, the (metallic) material of the gas-binding component may be supplied with electrical current, meaning that the heating is effected with the aid of resistance heating. It is of course alternatively possible to heat the surface of the gas-binding component in some other way, for example with the aid of inductive heating. The temperature to which the gas-binding component is heated for the regeneration depends on the nature of the bound contaminating substances.

In one variant of the method, the component is introduced into a cleaning chamber for regeneration of the gas-binding material. In the cleaning chamber, a suction may be provided, which enables the suction of the contaminating substances released on heating, such that cleaning of the gas-binding component can be conducted. For this purpose, a vacuum can be generated in the cleaning chamber, and a vacuum pump can be used to remove the contaminating substances released by suction. The gas-binding component may be disconnectably secured to a housing of the cleaning chamber in the same way as it is to the housing of the optical device, for example by fixed screw connection of the securing section on the outside of the housing of the cleaning chamber. The regenerated gas-binding component may be reused in the optical arrangement by exchanging it for a non-regenerated gas-binding component.

In a further variant, the steps of the method of regenerating the gas-binding component are conducted when a concentration of the gaseous contaminating substances in the interior of the housing exceeds a threshold value. The

concentration of the gaseous contaminating substances in the interior can be monitored with the aid of a sensor. If the sensor or a control device connected to the sensor detects that the threshold value has been exceeded, there may be an output to a user to the effect that an exchange of the gas-binding component(s) is required. The sensor may, for example, be a residual gas analyzer that may be disposed in the optical arrangement in any case, but it may also be another kind or specific kind of sensor. Alternatively, the method of regenerating, or the exchange of the gas-binding component, may be undertaken when the transmittance of the optical arrangement falls below a threshold value. But the transmittance of the optical arrangement is also affected by factors other than the concentration of the gaseous contaminating substances, and therefore the concentration of the contaminating substances in the interior generally constitutes a better index for the recognition of the necessity of an exchange of the gas-binding component.

Further features and advantages of the invention are evident from the description of working examples of the invention that follows, with reference to the figures of the drawing showing details essential to the invention, and from the claims. The individual features can each be realized individually by themselves or as a plurality in any desired combination in one variant of the invention.

Drawing

Working examples are shown in the schematic drawing and are elucidated in the description that follows. The figures show:

Fig. 1 a schematic of a meridional section of a projection exposure system for EUV projection lithography,

- Fig. 2 a schematic diagram of a process of deposition of HfO₂ products on a surface of a mirror of the projection exposure system of fig. 1,
- Fig. 3 a schematic diagram of a section of a housing of the projection exposure system of fig. 1, with a gas-binding component disconnectably secured thereto,
- Fig. 4 a schematic diagram of the gas-binding component of fig. 3 with a cooling device for in situ cooling,
- Figs. 5a,b schematic diagrams of gas-binding components having a heating device, and
- Fig. 6 a schematic diagram of multiple steps of a method of regenerating the gas-binding component.

In the description of the drawings that follows, identical reference signs are used for components that are the same or have the same function.

The essential components of an optical arrangement for EUV lithography in the form of a microlithographic projection exposure apparatus 1 are described by way of example below with reference to fig. 1. The description of the basic set-up of the projection exposure apparatus 1 and the components thereof should not be understood as restrictive in this case.

An embodiment of an illumination system 2 of the projection exposure apparatus 1 has, in addition to a light or radiation source 3, an illumination optical unit 4 for illuminating an object field 5 in an object plane 6. In an alternative embodiment, the light source 3 can also be provided as a module separate from the rest of the illumination system. In this case, the illumination system does not comprise the light source 3.

A reticle 7 arranged in the object field 5 is illuminated. The reticle 7 is held by a reticle holder 8. The reticle holder 8 is displaceable by way of a reticle displacement drive 9, in particular in a scanning direction.

An embodiment of an illumination system 2 of the projection exposure apparatus 1 has, in addition to a light or radiation source 3, an illumination optical unit 4 for illuminating an object field 5 in an object plane 6. In an alternative embodiment, the light source 3 can also be provided as a module separate from the rest of the illumination system. In this case, the illumination system does not comprise the light source 3.

For purposes of explanation, a Cartesian xyz coordinate system is depicted in Figure 1. The x direction extends perpendicular to the plane of the drawing. The y direction extends horizontally, and the z direction extends vertically. The scanning direction runs along the y-direction in Figure 1. The z direction runs perpendicular to the object plane 6.

The projection exposure apparatus 1 comprises a projection system 10. The projection system 10 serves for imaging the object field 5 into an image field 11 in an image plane 12. A structure on the reticle 7 is imaged onto a light-sensitive layer of a wafer 13 arranged in the region of the image field 11 in the image plane 12. The wafer 13 is held by a wafer holder 14. The wafer holder 14 is displaceable by way of a wafer displacement drive 15, in particular in the y direction. The displacement on the one hand of the reticle 7 by way of the reticle displacement drive 9 and on the other hand of the wafer 13 by way of the wafer displacement drive 15 can take place in such a way as to be synchronized with one another.

The radiation source 3 is an EUV radiation source. The radiation source 3 emits, in particular, EUV radiation 16, which is also referred to below as used

radiation, illumination radiation or illumination light. In particular, the used radiation has a wavelength in the range between 5 nm and 30 nm. The radiation source 3 may be a plasma source, for example an LPP source (Laser Produced Plasma) or a GDPP source (Gas Discharge Produced Plasma). It may also be a synchrotron-based radiation source. The radiation source 3 can be a free electron laser (FEL).

The illumination radiation 16 emanating from the radiation source 3 is focused by a collector mirror 17. The collector mirror 17 can be a collector mirror with one or more ellipsoidal and/or hyperboloidal reflection surfaces. The at least one reflection surface of the collector mirror 17 can be impinged on by the illumination radiation 16 with grazing incidence (GI), i.e. at angles of incidence of greater than 45° , or with normal incidence (NI), i.e. at angles of incidence of less than 45° . The collector mirror 17 can be structured and/or coated, firstly, for optimizing its reflectivity for the used radiation and, secondly, for suppressing extraneous light.

The illumination radiation 16 propagates through an intermediate focus in an intermediate focal plane 18 downstream of the collector mirror 17. The intermediate focal plane 18 can represent a separation between a radiation source module, having the radiation source 3 and the collector mirror 17, and the illumination optical unit 4.

The illumination optical unit 4 comprises a deflection mirror 19 and, arranged downstream thereof in the beam path, a first facet mirror 20. The deflection mirror 19 can be a plane deflection mirror or, alternatively, a mirror with a beam-influencing effect that goes beyond the purely deflecting effect. Alternatively or in addition, the deflection mirror 19 can be in the form of a spectral filter which separates a used light wavelength of the illumination radiation 16 from extraneous light with a wavelength deviating therefrom. The first facet mirror 20 comprises a multiplicity of individual first facets 21, which are also referred to as

field facets below. Figure 1 depicts only some of said facets 21 by way of example. In the beam path of the illumination optical unit 4, a second facet mirror 22 is arranged downstream of the first facet mirror 20. The second facet mirror 22 comprises a plurality of second facets 23.

The illumination optical unit 4 consequently forms a doubly faceted system. This fundamental principle is also referred to as a fly's eye condenser (fly's eye integrator). The individual first facets 21 are imaged into the object field 5 with the aid of the second facet mirror 22. The second facet mirror 22 is the last beam-shaping mirror or else, in fact, the last mirror for the illumination radiation 16 in the beam path upstream of the object field 5.

The projection system 10 comprises a plurality of mirrors M_i , which are consecutively numbered in accordance with their arrangement in the beam path of the projection exposure apparatus 1.

In the example depicted in Figure 1, the projection system 10 comprises six mirrors M_1 to M_6 . Alternatives with four, eight, ten, twelve or any other number of mirrors M_i are likewise possible. The penultimate mirror M_5 and the last mirror M_6 each have a through opening for the illumination radiation 16. The projection system 10 is a doubly obscured optical unit. The projection optical unit 10 has an image-side numerical aperture that is greater than 0.4 or 0.5 and can also be greater than 0.6, and can be for example 0.7 or 0.75.

Just like the mirrors of the illumination optical unit 4, the mirrors M_i can have a highly reflective coating for the illumination radiation 16.

Fig. 2 shows a detail of the projection exposure system 1 of fig. 1 with the first mirror M_1 of the projection optical unit 10 and with a mechanical component 25 disposed close to the first mirror M_1 . The mechanical component 25 may, for example, be an actuator, a sensor, a bearing and/or holding structure, a

housing portion, etc. A surface 26 of the component 25 is close to the exposure radiation 16 that impinges upon the first mirror M1. Accumulated on the surface 26 of the component are hydrogen-volatile contaminating substances 27 (HIO compounds), which may, for example, be phosphorus compounds, silicon compounds, zinc compounds, etc. The hydrogen-volatile contaminating substances 27 may be deposited on the mirror M1 and form a contamination layer 28 on the surface of the mirror M1, which leads to a loss of transmittance of the mirror M1.

The deposition of the contamination layer 28 on the mirror M1 can be effected in four steps (cf. also fig. 2): In a first step, the exposure radiation 16 reacts with molecular hydrogen H_2 present in the environment of the first mirror M1 or in the entire projection optical unit 10 to hydrogen ions H^+ or to hydrogen radicals H^* , i.e. a hydrogen plasma is formed. In a second step, the hydrogen plasma, i.e. H^+/H^* , reacts with hydrogen-volatile contaminants 27 to a volatile compound, typically to a volatile hydride, which is identified as HIO product in fig. 2, and which is a gaseous contaminating substance 27a. In a third step, the gaseous contaminating substance 27a gets from the surface 26 of the component 25 to the surface of the first mirror M1. In a fourth step, the contamination layer 28 is formed there by reaction of the HIO product with the material of an outer layer at the surface of the first mirror M1 to a nonvolatile compound.

The formation of the contamination layer 28 on the first mirror M1 or on the mirrors M_i of the projection optical unit 10 and on the optical elements 19, 20, 22 of the exposure optical unit 4 in the course of operation of the projection exposure system 1 leads to a loss of transmittance of the projection exposure system 1.

The projection optical unit 10 shown in fig. 1 with the six mirrors M1 to M6 is disposed in an interior 31 of a housing 30, of which fig. 3 shows just a small detail. The housing 30 may alternatively also be a housing of the illumination

optical unit 4 or another housing of the projection exposure system 1, in the interior 31 of which there exists a vacuum environment.

In order to counteract the loss of transmittance described in connection with fig. 2, the projection exposure system 1 has multiple gas-binding components, of which fig. 3 shows one gas-binding component 32 by way of example.

The gas-binding component 32 has two surfaces 33a, 33b, on which a gas-binding material is formed or provided. The gas-binding material serves to bind the or a portion of the gaseous contaminating substances 27a present in the interior 31. The gas-binding material in the example shown is a material selected from the group comprising: Ta, Nb, Ti, Zr, Th, Ni, Ru. This and other, especially metallic, materials or alloys, enable binding of the or a majority of the gaseous contaminating substances 27a present in the interior 31 of the housing 30 of the projection exposure system 1.

With increasing operating time of the projection exposure system 1, there is an increase in the amount of gaseous contaminating substances 27a that have to be bound to the respective surface 33a,b by the gas-binding material. However, the capacity of the surfaces 33a,b of the gas-binding component 32 for binding of the gaseous contaminating substances 27a is limited, such that the effect of the gas-binding material and hence of the gas-binding component 32 decreases with increasing operating time of the projection exposure system 1.

In order to ensure high transmittance in the projection exposure system 1 in spite of the decreasing gas-binding action of the gas-binding component 32 with increasing operating time, the gas-binding component 32 shown in fig. 3 is designed to be exchangeable, meaning that it can be removed from the housing 30 or from the projection exposure system 1.

In order to enable the removal, the gas-binding component 32 is secured to the housing 30 via a connection 34 that can be disconnected from an outer face 30a of the housing 30. The disconnectable connection 34 in the example shown is a screw connection, but it may also be another kind of disconnectable connection, for example a clamp connection or the like. For the establishment of the connectable connection, the gas-binding component 32 has a securing section 35 which, in the example shown, is designed in the manner of a flange. The securing section 35 is brought into two-dimensional contact on the outer face 30a of the housing 30 and, with the aid of securing screws indicated by dotted lines in fig. 3, screwed to the outer face 30a of the housing 30. It will be apparent that the securing section 35 need not necessarily be planar, as shown in fig. 3, but may also be curved or angled.

The gas-binding component 32 also has a plate section 36 which adjoins the securing section 35 and which projects via an opening formed in the housing 30 into the housing 30 of the projection exposure system 1. The plate section 36, in the example shown in fig. 3, is a steel plate with the gas-binding material applied in the form of a coating 37 to either of its two opposite surfaces 33a, 33b. It is possible that the coating 37 is formed from the same gas-binding material on the two opposite surfaces 33a, 33b, but it is also possible that the coating 37 on the two surfaces 33a, 33b consists of a respectively different gas-binding material or of multiple different gas-binding materials, in order to bind different kinds of gaseous contaminating substances 27a.

The plate section 36 of the gas-binding component 32 is not necessarily a planar section; it may instead be in curved form or have virtually any geometry. More particularly, the geometry of the plate section may be matched to the geometry of a component to be shielded in the interior 31, for example to the geometry of the mechanical component 25 described in connection with fig. 2. It will be apparent that the plate section 36 of the gas-binding component 32

should not project into the beam path of the EUV radiation 5 of the projection exposure system 1.

The gas-binding component 32, or more specifically the plate section 36 of the gas-binding component 32, may be cooled with the aid of a cooling device 38 shown in fig. 4 in the installed state in the housing 30, in order to freeze out gaseous contaminating substances 27a present in the interior 31 at the surfaces 33a, 33b. For this purpose, in the example shown in fig. 4, a cooling duct is introduced into the plate section 36 in the form of the steel sheet. A loop of a cooling wire is embedded into the cooling duct, which is cooled with the aid of the cooling device 38.

In the example shown, the cooling device 38 is based on the principle of liquid cooling and has a closed liquid circuit with a pump for circulation of the liquid in the liquid circuit and hence also in the cooling wire. The cooling device 38 also comprises a cooling unit for cooling of the cooling liquid. The cooling liquid may be cooling water, which is cooled, for example, by a cooling unit in the form of a fan or the like. The cooling device 38 may alternatively be designed for cooling with another type of cooling liquid that can be cooled down, for example, to lower temperatures than is the case with cooling water. The cooling of the gas-binding component 32 or of the surfaces 33a, 33b allows the gas-binding action thereof to be enhanced.

The projection exposure system 1 has a sensor that monitors the concentration K of the gaseous contaminating substances 27a in the interior 31. The sensor may, for example, be a residual gas analyser or another type of sensor suitable for monitoring the concentration or partial pressure of the gaseous contaminating substances 27a in the interior 31. If the concentration K of the gaseous contaminating substances 27a in the interior 31 is above a threshold K_s , a message can be sent to a user that an exchange of the gas-binding

component 32 or of all gas-binding components of the projection exposure system 1 is required.

For the withdrawal of the gas-binding component 32, the screw connection 34 is disconnected and the gas-binding component 32 is withdrawn from the housing 30, as indicated by an arrow in fig. 3. In this case, the plate section 36 of the gas-binding component 32 is moved through a slot-shaped opening in the housing 30 in a linear movement in the direction of the outside 30a of the housing 30. After withdrawal from the housing 30, the gas-binding component 32 is removed from the projection exposure system 1 and exchanged for another gas-binding component 32 of the same design, the gas-binding material of which has a stronger gas-binding action. In order to enable rapid exchange of the gas-binding component 32, a stock of gas-binding components 32 with unspent or regenerated gas-binding material (see below) may be stored in a magazine or the like.

The exchange of the gas-binding component 32 described further up can be effected when the vacuum in the interior 31 is broken, as is the case, for example, in a pause in operation. Alternatively, it is also possible that the exchange of the gas-binding component 32 is conducted without the breaking of the vacuum in the interior 31. In order to achieve this, in the example shown in fig. 6, a vacuum lock 39 shown by dotted lines is provided in the housing 30, which enables, for the exchange or withdrawal of the gas-binding component 32, severing of a connection between a part-volume 31a of the interior 31 of the housing 30 in which the surface 33a, 33b with the gas-binding material or the plate section 36 are disposed from the rest of the interior 31b of the housing 30 in which the optical element M1 is disposed. Alternatively, it is also possible to connect a component provided with a vacuum lock to the outer face 30a of the housing 30 in order to separate a part-volume of the environment of the housing 30 in which the securing section 35 is disconnectably secured to the outer face 30a of the housing 30 from the rest of the environment of the housing 30, such

that the gas-binding component 32 can be removed from the housing 30 without breaking the vacuum.

It is possible that the gas-binding component 23 withdrawn from the projection exposure system 1, or more specifically the gas-binding material thereof, can be regenerated. For that purpose, the gas-binding component 32 is heated up by means of a heating device 41, as shown in figs. 5a,b. The heating device 41, in the example shown, takes the form of a resistance heater and introduces a heating current into the gas-binding component 32 in order to heat it up to a temperature high enough for the bound contaminating substances 27a to be converted to the gas phase and evaporated off the respective surface 33a, 33b. Alternatively, the heating device 41 may also be designed, for example, as an inductive heater in order to heat the gas-binding component 32 up to the temperature required.

The gas-binding component 32 shown in fig. 5b differs from the gas-binding component 32 shown in fig. 5a in that it has three plate sections 36a-c, which, in the example shown, are aligned parallel to one another and at right angles to the securing section 35. The three plate sections 36a-c increase the surface area available for the binding of the gaseous contaminating substances 27a. It will be apparent that the number of three plate sections 36a-c has been chosen merely for illustrative purposes, and that the gas-binding component 32 may alternatively have one, three, four or a multitude of plate sections. It will be apparent that it is possible to depart from the regular or equidistant arrangement of the plate sections 36a-c shown in fig. 5b.

For the regeneration of the gas-binding material, it is favorable if the gas-binding component 32, after being withdrawn from the housing 30, is introduced into a cleaning chamber 42 as shown in fig. 6. The gas-binding component may be secured in a disconnectable manner (via a screw connection) to the housing of the cleaning chamber 42 in a manner described further up in connection with

fig. 3. The plate section 36 projects here through an opening in the cleaning chamber 42 or in the housing into an interior of the cleaning chamber 42. The interior of the cleaning chamber 42 is connected to a vacuum pump 43. The vacuum pump 43 enables pumping-out of the contaminating gaseous substances 27a that are released on heating, such that they cannot be precipitated again on the surfaces 33a,b of the gas-binding component 32. After regeneration, the gas-binding component 32 can be withdrawn from the cleaning chamber 42 and is available for reincorporation into the projection exposure system 1 or into the housing 30.

Claims

1. An optical arrangement (1) for EUV lithography, comprising:
a housing (30),
at least one optical element (M1 to M6) disposed within an interior (31) of the housing (30),
at least one gas-binding component (32) having at least one surface (33a, 33b) with a gas-binding material for binding of gaseous contaminating substances (27a) present in the interior (31),
wherein
the gas-binding component (32) is secured to the housing (30) via a connection (34) which can be disconnected from an outer face (30a) of the housing (30) in order to remove the gas-binding component (32) from the housing (30).
2. The optical arrangement as claimed in claim 1, in which the gas-binding component (32) has a securing section (35) for disconnectable securing to the outer face (30a) of the housing (30).
3. The optical arrangement as claimed in claim 2, in which the securing section (35) is secured to the outer face (30a) of the housing (30) via a disconnectable connection in the form of a screw connection (34).
4. The optical arrangement as claimed in any of the preceding claims, in which the gas-binding material is applied to the surface (33a, 33b) in the form of a coating (37).
5. The optical arrangement as claimed in any of the preceding claims, in which the gas-binding material is selected from the group comprising: Ta, Nb, Ti, Zr, Th, Ni, Ru.

6. The optical arrangement as claimed in any of the preceding claims, in which the gas-binding component (32) has at least one plate section (36) on which the at least one surface (33a, 33b) having the gas-binding material is formed.
7. The optical arrangement as claimed in claim 6, in which the plate section (36) has a first surface (33a) with a gas-binding material and a second surface (33b), opposite the first, with a gas-binding material.
8. The optical arrangement as claimed in any of the preceding claims, further comprising: at least one cooling device (38) for cooling the at least one surface (33a, 33b) having the gas-binding material.
9. The optical arrangement as claimed in any of the preceding claims, further comprising: at least one vacuum lock (39) for severing a connection of a part-volume (31a) of the interior (31) of the housing (30) in which the surface (33a, 33b) with the gas-binding material is disposed from the remaining interior (31a) of the housing (30), or for separating a sub-volume of the environment of the housing (30) in which the securing section (35) is disconnectably secured on the outer face (30a) of the housing (30) from the rest of the environment of the housing (30).
10. A method of regenerating at least one gas-binding component (32) of the optical arrangement (1) as claimed in any of the preceding claims, comprising:
disconnecting (34) the gas-binding component (32) from the housing (30),
removing the gas-binding component (32) from the optical arrangement (1), and
regenerating the gas-binding material by heating the surface (33a, 33b) with the gas-binding material.

11. The method as claimed in claim 10, in which the gas-binding component (32) is introduced into a cleaning chamber (42) for regeneration of the gas-binding material.
12. The method as claimed in claim 10 or 11, in which the steps of the method of regenerating the gas-binding component (32) are conducted when a concentration (K) of the gaseous contaminating substances (27b) in the interior (31) of the housing (30) exceeds a threshold value (K_s).

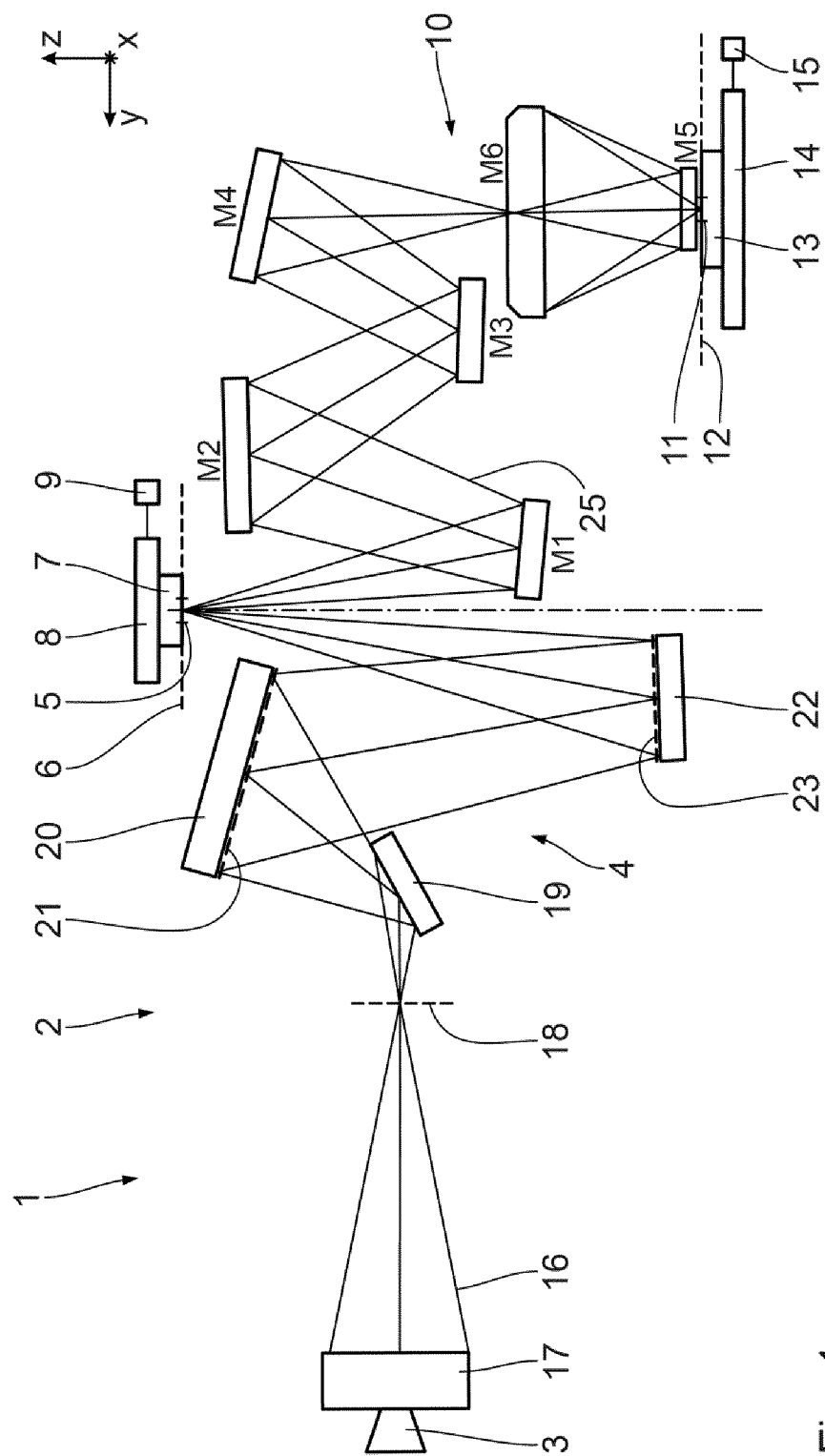


Fig. 1

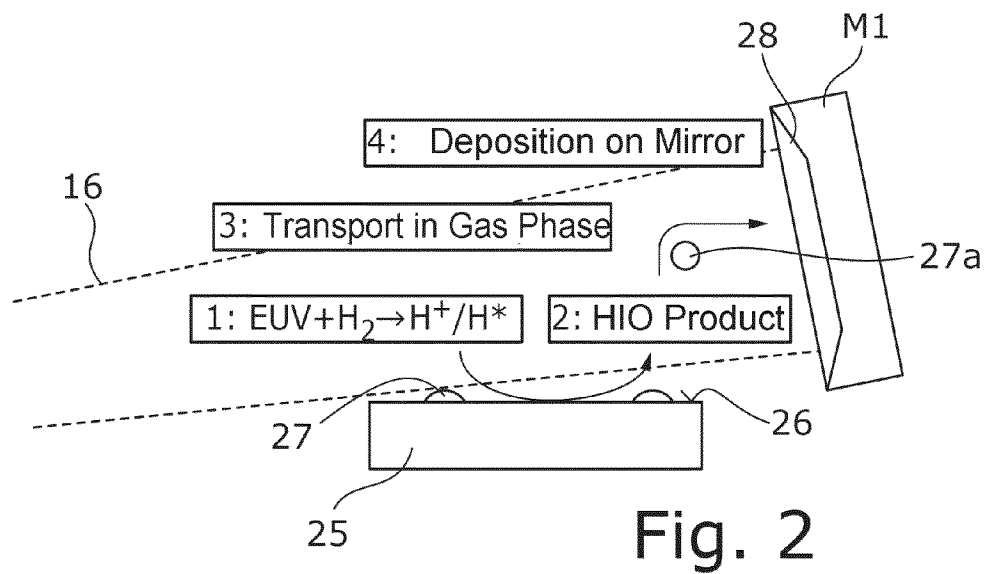
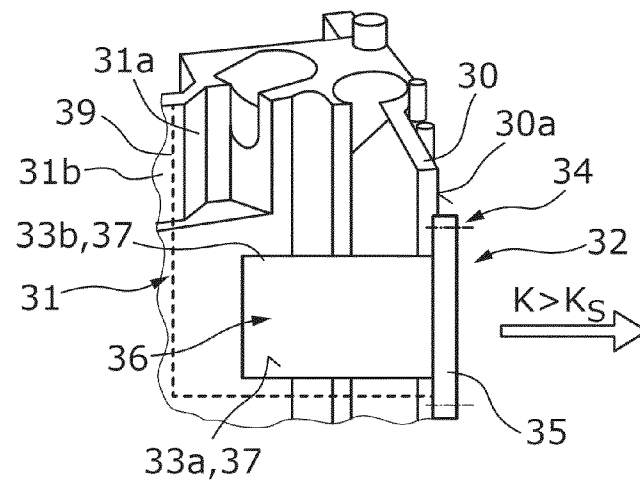


Fig. 3

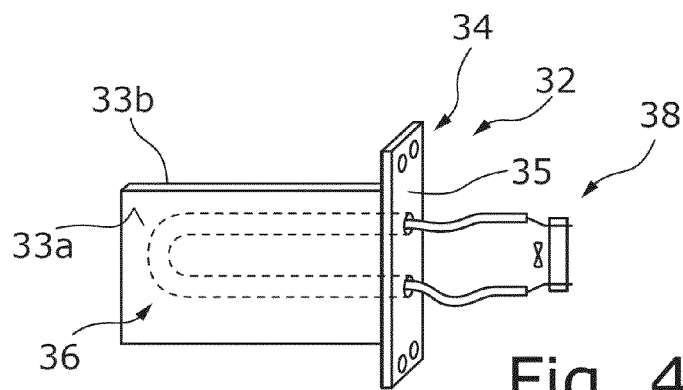
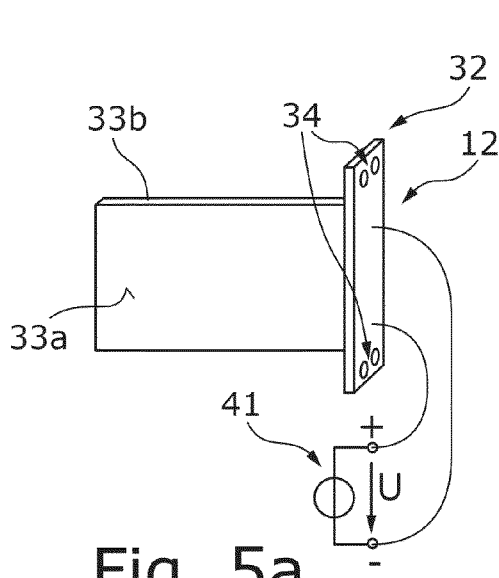
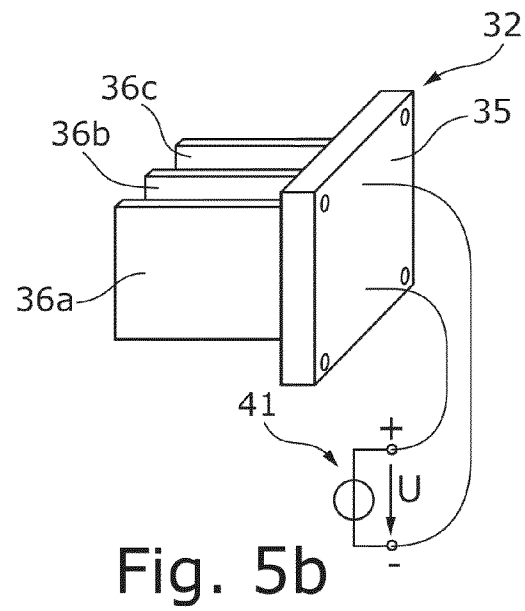
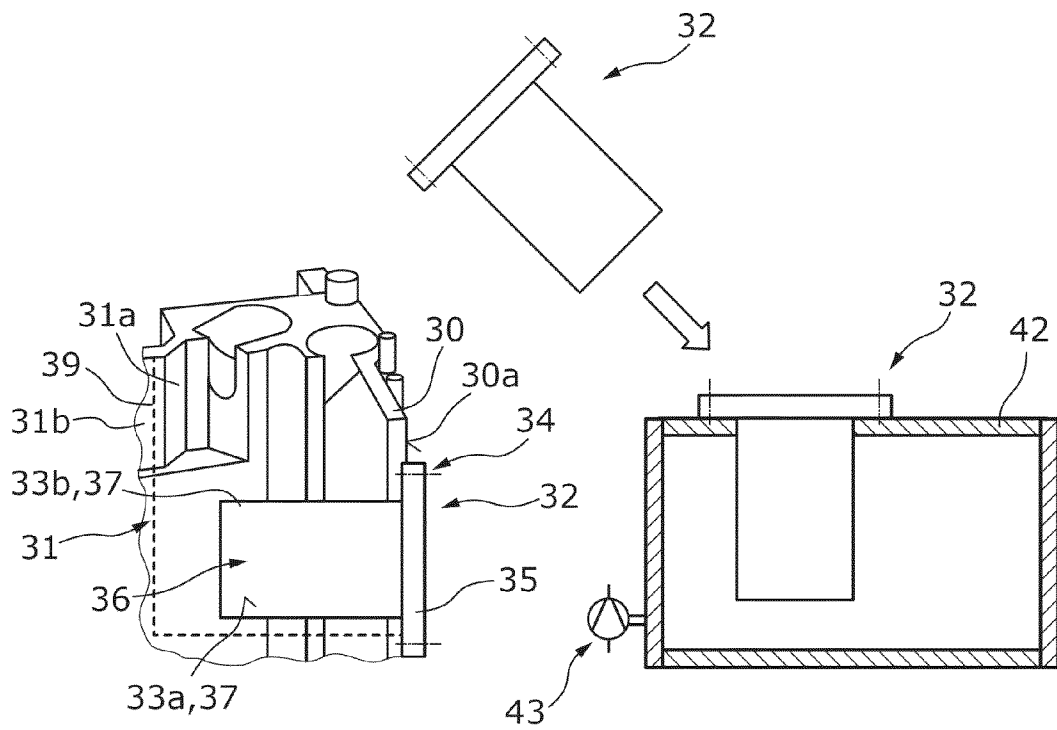


Fig. 4



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2022/064929

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		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010/309446 A1 (MANINI PAOLO [IT] ET AL) 9 December 2010 (2010-12-09) paragraphs [0001], [0013], [0014], [0022] - [0024], [0028] - [0030]; figures 1,2	1-12
X	CONTE A ET AL: "NEG (non evaporable getter) pumps for organic compounds and water removal in EUVL tools", PROCEEDINGS OF SPIE, IEEE, US, vol. 6921, 14 March 2008 (2008-03-14), pages 692138-1, XP002529331, DOI: 10.1117/12.776061 ISBN: 978-1-62841-730-2 abstract sections 1- 3	1
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 30 September 2022		Date of mailing of the international search report 11/10/2022
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Weckesser, Jens

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Information on patent family members

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