



(51) International Patent Classification:

G03F 7/20 (2006.01) H01L 21/683 (2006.01)

(21) International Application Number:

PCT/EP2020/052945

(22) International Filing Date:

06 February 2020 (06.02.2020)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

19160194.7 01 March 2019 (01.03.2019) EP

(71) Applicant: ASML NETHERLANDS B.V. [NL/NL]; P.O. Box 324, 5500 AH Veldhoven (NL).

(72) Inventors: GUAN, Tiannan; P.O. Box 324, 5500 AH Veldhoven (NL). MEULENDIJKS, Antonius, Arnoldus; P.O. Box 324, 5500 AH Veldhoven (NL). VAN GILS, Petrus, Jacobus, Maria; P.O. Box 324, 5500 AH Veldhoven (NL). VERSCHUREN, Marinus, Augustinus, Christiaan; P.O. Box 324, 5500 AH Veldhoven (NL).

(74) Agent: PEI, Fei; P.O. Box 324, 5500 AH Veldhoven (NL).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

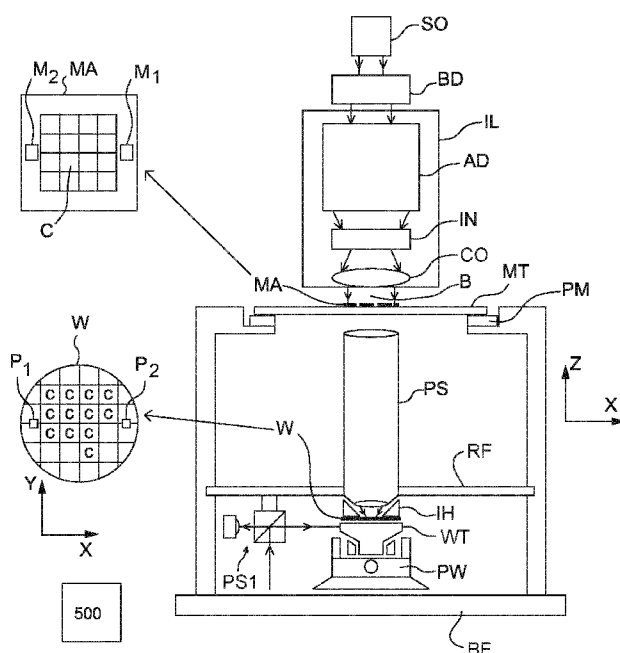
(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: OBJECT HOLDER COMPRISING AN ELECTROSTATIC CLAMP

Fig. 1



(57) Abstract: Disclosed herein is an object holder arranged to support an object, the object holder comprising at least a core layer and an electrode layer; wherein the object holder has a surface that is arranged to be clamped, by an electrostatic clamp, to a table for the object holder; wherein, the object holder comprises a plurality of burl arrangements with each burl arrangement comprising a burl body, a trench, a burl electrode and an insulating part; wherein, for each burl arrangement, part of the burl body protrudes from said surface of the object holder, the trench surrounds the burl body in a plane that is parallel to said surface of the object holder, the trench extends, in a direction that is orthogonal to said surface of the object holder, from said surface of the object holder to at least through the electrode layer, the burl electrode is comprised by the electrode layer and surrounds the trench, and the insulating part is comprised by the electrode layer and surrounds the burl electrode; wherein the electrode layer further comprises one or more clamping electrodes that are electrodes of the electrostatic clamp that is arranged to clamp said surface to a table for the object holder, and, within the electrode layer, each of the insulating parts of a burl arrangement is surrounded by a clamping electrode; and wherein the object holder comprises one or more electrically conducting vias arranged between each burl electrode and the core layer.

OBJECT HOLDER COMPRISING AN ELECTROSTATIC CLAMP**CROSS-REFERENCE TO RELATED APPLICATIONS**

[0001] This application claims priority of EP application 19160194.7, which was filed on 1 March, 2019 and which is incorporated herein in its entirety by reference.

FIELD

[0002] The present invention relates to an object holder for use in a lithographic apparatus. The object holder comprises one or more electrostatic clamps arranged to clamp the object holder to a table and/or to clamp an object to the object holder.

BACKGROUND

[0003] A lithographic apparatus is a machine that applies a desired pattern onto a substrate, usually onto a target portion of the substrate. A lithographic apparatus can be used, for example, in the manufacture of integrated circuits (ICs). In that instance, a patterning device, which is alternatively referred to as a mask or a reticle, may be used to generate a circuit pattern to be formed on an individual layer of the IC. This pattern can be transferred onto a target portion (e.g. comprising part of, one, or several dies) on a substrate (e.g. a silicon wafer). Transfer of the pattern is typically via imaging onto a layer of radiation-sensitive material (resist) provided on the substrate. In general, a single substrate will contain a network of adjacent target portions that are successively patterned. Known lithographic apparatus include so-called steppers, in which each target portion is irradiated by exposing an entire pattern onto the target portion at one time, and so-called scanners, in which each target portion is irradiated by scanning the pattern through a radiation beam in a given direction (the "scanning"-direction) while synchronously scanning the substrate parallel or anti-parallel to this direction. It is also possible to transfer the pattern from the patterning device to the substrate by imprinting the pattern onto the substrate.

[0004] It has been proposed to immerse the substrate in the lithographic projection apparatus in a liquid having a relatively high refractive index, e.g. water, so as to fill a space between the final element of the projection system and the substrate. The liquid may be distilled water, although another liquid can be used, and techniques are described herein with reference to a liquid. However, another fluid may be suitable, particularly a wetting fluid, an incompressible fluid and/or a fluid with higher refractive index than air, desirably a higher refractive index than water. Fluids excluding gases are particularly desirable. The point of this is to enable imaging of smaller features since the exposure radiation will have a shorter wavelength in the liquid. (The effect of the liquid may also be regarded as increasing the effective numerical aperture (NA) of the system and also increasing the depth of focus.) Other immersion liquids have been proposed, including water with solid particles (e.g. quartz) suspended

therein, or a liquid with a nano-particle suspension (e.g. particles with a maximum dimension of up to 10 nm). The suspended particles may or may not have a similar or the same refractive index as the liquid in which they are suspended. Other liquids which may be suitable include a hydrocarbon, such as an aromatic, a fluorohydrocarbon, and/or an aqueous solution.

5 **[0005]** In a conventional lithography apparatus, the substrate to be exposed may be supported by a substrate holder (i.e. the object that directly supports a substrate) which in turn is supported by a substrate table (mirror block or stage, i.e. the object such as table that supports the substrate holder and provides the upper surface surrounding the substrate holder). The substrate holder is often a flat rigid disc corresponding in size and shape to the substrate (although it may have a different size or shape). It
10 has an array of projections, referred to as burls or pimples, projecting from at least one side. The substrate holder may have an array of projections on two opposite sides. In this case, when the substrate holder is placed on the substrate table, the main body of the substrate holder is held a small distance above the substrate table while the ends of the burls on one side of the substrate holder lie on the surface of the substrate table. Similarly, when the substrate rests on the top of the burls on the opposite side of
15 the substrate holder, the substrate is spaced apart from the main body of the substrate holder. The purpose of this is to help prevent a particle (i.e. a contaminating particle such as a dust particle) which might be present on either the substrate table or substrate holder from distorting the substrate holder or substrate. Since the total surface area of the burls is only a small fraction of the total area of the substrate or substrate holder, it is highly probable that any particle will lie between burls and its presence will
20 have no effect. Often, the substrate holder and substrate are accommodated within a recess in the substrate table so that the upper surface of the substrate is substantially coplanar with the upper surface of the substrate table.

[0006] Due to the high accelerations experienced by the substrate in use of a high- throughput lithographic apparatus, it is not sufficient to allow the substrate simply to rest on the burls of the
25 substrate holder. It is clamped in place. Two methods of clamping the substrate in place are known - vacuum clamping and electrostatic clamping. In vacuum clamping, the space between the substrate holder and substrate and optionally between the substrate table and substrate holder are partially evacuated so that the substrate is held in place by the higher pressure of gas or liquid above it. Vacuum clamping however may not be used where the beam path and/or the environment near the substrate or
30 substrate holder is kept at a low or very low pressure, e.g. for extreme ultraviolet (EUV) radiation lithography. In this case, it may not be possible to develop a sufficiently large pressure difference across the substrate (or substrate holder) to clamp it. Electrostatic clamping may therefore be used. In electrostatic clamping, a potential difference is established between the substrate, or an electrode plated on its lower surface, and an electrode provided on, or in, the substrate table and/or substrate holder. The
35 two electrodes behave as a large capacitor and substantial clamping force can be generated with a reasonable potential difference. An electrostatic arrangement can be such that a single pair of electrodes, one on the substrate table and one on the substrate, clamps together the complete stack of substrate

table, substrate holder and substrate. In a known arrangement, one or more electrodes may be provided on, or in, the substrate holder so that the substrate holder is clamped to the substrate table and the substrate is separately clamped to the substrate holder.

[0007] There is a need to improve substrate holders that comprise one or more electrostatic clamps for clamping a substrate holder to a substrate table and/or a substrate to a substrate holder. More generally, there is a need to improve an object holder, such as patterning device holder, that comprises one or more electrostatic clamps for holding the object holder to a table and/or holding an object against the object holder.

SUMMARY

[0008] According to a first aspect of the invention, there is provided an object holder arranged to support an object, the object holder comprising at least a core layer and an electrode layer; wherein the object holder has a surface that is arranged to be clamped, by an electrostatic clamp, to a table for the object holder; wherein, the object holder comprises a plurality of burl arrangements with each burl arrangement comprising a burl body, a trench, a burl electrode and an insulating part; wherein, for each burl arrangement, part of the burl body protrudes from said surface of the object holder, the trench surrounds the burl body in a plane that is parallel to said surface of the object holder, the trench extends, in a direction that is orthogonal to said surface of the object holder, from said surface of the object holder to at least through the electrode layer, the burl electrode is comprised by the electrode layer and surrounds the trench, and the insulating part is comprised by the electrode layer and surrounds the burl electrode; wherein the electrode layer further comprises one or more clamping electrodes that are electrodes of the electrostatic clamp that is arranged to clamp said surface to a table for the object holder, and, within the electrode layer, each of the insulating parts of a burl arrangement is surrounded by a clamping electrode; and wherein the object holder comprises one or more electrically conducting vias arranged between each burl electrode and the core layer. Alternatively or additionally the one or more electrically conducting vias extend between each burl electrode and the core layer.

[0009] Preferably, the object holder further comprises at least an insulation layer and a dielectric layer; wherein: the insulation layer is arranged between the core layer and the electrode layer; the dielectric layer is arranged between the electrode layer and said surface of the substrate; and, for each burl arrangement, the trench extends through the dielectric layer and the insulation layer.

[00010] Preferably, for each burl arrangement, the trench extends into at least part of the core layer.

[00011] Preferably, for each burl arrangement, the burl body comprises a metal layer at the end of the part of the burl body that protrudes from the surface.

[00012] Preferably, each burl arrangement further comprises one or more electrically conducting vias arranged between said metal layer and the core layer.

[00013] Preferably, the electrode layer comprises two clamping electrodes.

[00014] Preferably, the core layer is at a ground potential.

[00015] Preferably, said surface is circular and the plurality of burl arrangements are positioned on said surface with a substantially uniform axial distribution.

[00016] Preferably, the object is a substrate or a patterning device.

5 [00017] According to a second aspect of the invention, there is provided an object holder for supporting an object, the object holder comprising at least a core layer and an electrode layer; wherein the object holder has a surface that is arranged to be clamped, by an electrostatic clamp, to the object; wherein, the object holder comprises a plurality of burl arrangements; wherein each burl arrangement comprises a burl body and a burl electrode; wherein, for each burl arrangement, an end of the burl body
10 provides a raised part of said surface of the object holder and the burl electrode is arranged on at least the end of the burl body that provides the raised part; wherein the electrode layer comprises one or more clamping electrodes that are electrodes of the electrostatic clamp that is arranged to clamp said surface to an object; wherein the object holder comprises one or more electrically conducting vias that extend between each burl electrode and the core layer; and wherein the electrode layer comprises a plurality of
15 insulating parts that are arranged such that the part of each via that passes through the electrode layer is surrounded by an insulating part.

[00018] Preferably, the object holder further comprises at least an insulation layer and a dielectric layer; wherein the insulation layer is arranged between the core layer and the electrode layer; and wherein the dielectric layer is arranged between the electrode layer and said surface of the substrate;
20 and each via extends through the dielectric layer and the insulation layer.

[00019] Preferably, for each burl arrangement, the burl electrode is further provided on side walls of the burl body and, in a plane parallel to said surface, around the base of the burl body.

[00020] Preferably, each via is attached at one end to the part of a burl electrode that is provided around the base of each burl body.

25 [00021] Preferably, the electrode layer comprises two clamping electrodes.

[00022] Preferably, the core layer is at a ground potential.

[00023] Preferably, the object is a substrate or a patterning device.

[00024] According to a third aspect of the invention, there is provided an object holder arrangement for supporting an object, the object holder arrangement comprising: a object holder according to the
30 first aspect arranged to electrostatically clamp the object holder to a table for the object holder; and/or a object holder according to the second aspect arranged to electrostatically clamp an object to the object holder.

[00025] According to a forth aspect of the invention, there is provided a lithographic apparatus comprising an object holder arrangement according to the third aspect.

BRIEF DESCRIPTION OF THE DRAWINGS

[00026] Embodiments of the invention will now be described, by way of example only, with reference to the accompanying schematic drawings, in which:

[00027] Figure 1 depicts a lithographic apparatus;

5 [00028] Figures 2 and 3 depict a liquid supply system for use in a lithographic projection apparatus;

[00029] Figure 4 depicts a further liquid supply system for use in a lithographic projection apparatus;

[00030] Figure 5 depicts, in cross-section, a barrier member which may be used as an immersion liquid supply system;

10 [00031] Figure 6 depicts a lithographic apparatus;

[00032] Figure 7 is a more detailed view of the apparatus of Figure 6;

[00033] Figure 8 is a more detailed view of the source collector of the apparatus of Figures 6 and 7;

[00034] Figure 9 depicts in cross-section a substrate table and a substrate holder;

15 [00035] Figure 10 shows a cross section through part of a known object holder;

[00036] Figure 11A shows the lower surface of a known object holder;

[00037] Figure 11B shows the structures in an electrode layer of a known object holder;

[00038] Figure 11C shows a cross-section through a known object holder;

20 [00039] Figure 12A shows the ends of burl bodies of long burls according to an embodiment;

[00040] Figure 12B shows part of an electrode layer according to an embodiment;

[00041] Figure 12C shows a cross-section through a long burl according to an embodiment;

[00042] Figure 13 shows a cross-section through a long burl according to an embodiment;

[00043] Figure 14 is a view of an electrode layer according to an embodiment

25 [00044] Figure 15 shows a short burl that may be provided on the upper surface of an object holder according to an embodiment; and

[00045] Figure 16 shows a short burl that may be provided on the upper surface of an object holder according to an embodiment.

30 [00046] While the invention is susceptible to various modifications and alternative forms, specific embodiments thereof are shown by way of example in the drawings and may herein be described in detail. The drawings may not be to scale. It should be understood, however, that the drawings and detailed description thereto are not intended to limit the invention to the particular form disclosed, but on the contrary, the intention is to cover all modifications, equivalents and alternatives falling within the spirit and scope of the present invention as defined by the appended claims.

DETAILED DESCRIPTION

[00047] Figures 1 and 6 schematically depict lithographic apparatuses that may use an electrostatic clamp according to an embodiment of the invention. Each apparatus may comprise:

[00048] - an illumination system (illuminator) IL configured to condition a radiation beam B (e.g. UV radiation, DUV radiation or EUV radiation);

[00049] - a support structure (e.g. a mask table) MT constructed to support a patterning device (e.g. a mask) MA and connected to a first positioner PM configured to accurately position the patterning device in accordance with certain parameters;

[00050] - a substrate table (e.g. a wafer table) WT constructed to hold a substrate holder, the substrate holder being arranged to hold a substrate (e.g. a resist-coated wafer) W, and connected to a second positioner PW configured to accurately position the substrate in accordance with certain parameters. A substrate holder as described herein can be used to hold the substrate W on the substrate table WT; and

[00051] - a projection system (e.g. a refractive or reflective projection lens system) PS configured to project a pattern imparted to the radiation beam B by patterning device MA onto a target portion C (e.g. comprising one or more dies) of the substrate W.

[00052] The illumination system may include various types of optical components, such as refractive, reflective, magnetic, electromagnetic, electrostatic or other types of optical components, or any combination thereof, for directing, shaping, or controlling radiation.

[00053] The support structure MT holds the patterning device. The support structure MT holds the patterning device in a manner that depends on the orientation of the patterning device, the design of the lithographic apparatus, and other conditions, such as for example whether or not the patterning device is held in a vacuum environment. The support structure MT can use mechanical, vacuum, electrostatic or other clamping techniques to hold the patterning device. The support structure MT may be a frame or a table, for example, which may be fixed or movable as required. The support structure MT may ensure that the patterning device is at a desired position, for example with respect to the projection system. Any use of the terms "reticle" or "mask" herein may be considered synonymous with the more general term "patterning device."

[00054] The term "patterning device" used herein should be broadly interpreted as referring to any device that can be used to impart a radiation beam with a pattern in its cross-section such as to create a pattern in a target portion of the substrate. It should be noted that the pattern imparted to the radiation beam may not exactly correspond to the desired pattern in the target portion of the substrate, for example if the pattern includes phase-shifting features or so called assist features. Generally, the pattern imparted to the radiation beam will correspond to a particular functional layer in a device being created in the target portion, such as an integrated circuit.

[00055] The patterning device may be transmissive or reflective. Examples of patterning devices include masks, programmable mirror arrays, and programmable LCD panels. Masks are well known in lithography, and include mask types such as binary, alternating phase-shift, and attenuated phase-shift, as well as various hybrid mask types. An example of a programmable mirror array employs a matrix arrangement of small mirrors, each of which can be individually tilted so as to reflect an incoming radiation beam in different directions. The tilted mirrors impart a pattern in a radiation beam which is reflected by the mirror matrix.

[00056] The term "projection system" used herein, like the term "illumination system", should be broadly interpreted as encompassing any type of projection system, including refractive, reflective, catadioptric, magnetic, electromagnetic and electrostatic optical systems or other types of optical components, or any combination thereof, as appropriate for the exposure radiation being used, or for other factors such as the use of an immersion liquid or the use of a vacuum. Any use of the term "projection lens" herein may be considered as synonymous with the more general term "projection system". The projection system, like the illumination system, may include various types of optical components, such as refractive, reflective, magnetic, electromagnetic, electrostatic or other types of optical components, or any combination thereof, as appropriate for the exposure radiation being used, or for other factors such as the use of a vacuum. It may be desired to use a vacuum for EUV radiation since other gases may absorb too much radiation. A vacuum environment may therefore be provided to the whole beam path with the aid of a vacuum wall and vacuum pumps.

[00057] As depicted in Figure 1, the apparatus is of a transmissive type (e.g. employing a transmissive mask). Alternatively, as depicted in Figure 6, the apparatus may be of a reflective type (e.g. employing a programmable mirror array of a type as referred to above, or employing a reflective mask).

[00058] The lithographic apparatus may be of a type having two or more tables (or stage(s) or support(s)) which may be referred to as dual stage, e.g., two or more substrate tables or a combination of one or more substrate tables and one or more sensor or measurement tables. In such "multiple stage" machines the additional tables may be used in parallel, or preparatory steps may be carried out on one or more tables while one or more other tables are being used for exposure. The lithographic apparatus may have two or more patterning device tables (or stage(s) or support(s)) which may be used in parallel in a similar manner to substrate, sensor and measurement tables.

[00059] Referring to Figures 1 and 6, the illuminator IL receives a radiation beam from a radiation source SO in Figure 1 or a source collector apparatus SO in Figure 6. The source and the lithographic apparatus may be separate entities, for example when the source is an excimer laser. In such cases, the source is not considered to form part of the lithographic apparatus and the radiation beam is passed from the source SO to the illuminator IL with the aid of a beam delivery system BD comprising, for example, suitable directing mirrors and/or a beam expander. In other cases the source may be an integral part of

the lithographic apparatus, for example when the source is a mercury lamp. The source SO and the illuminator IL, together with the beam delivery system BD if required, may be referred to as a radiation system.

[00060] Methods to produce EUV radiation include, but are not necessarily limited to, converting a material into a plasma state that has at least one element, e.g., xenon, lithium or tin, with one or more emission lines in the EUV range. In one such method, often termed laser produced plasma ("LPP") the plasma can be produced by irradiating a fuel, such as a droplet, stream or cluster of material having the desired line-emitting element, with a laser beam. The source collector apparatus SO may be part of an EUV radiation system including a laser, not shown in Figure 6, to provide the laser beam exciting the fuel. The resulting plasma emits output radiation, e.g., EUV radiation, which is collected using a radiation collector, disposed in the source collector apparatus. The laser and the source collector apparatus may be separate entities, for example when a CO₂ laser is used to provide the laser beam for fuel excitation. In such cases, the laser is not considered to form part of the lithographic apparatus and the radiation beam is passed from the laser to the source collector apparatus with the aid of a beam delivery system comprising, for example, suitable directing mirrors and/or a beam expander. In other cases the source may be an integral part of the source collector apparatus, for example when the source is a discharge produced plasma EUV generator, often termed as a DPP source.

[00061] The illuminator IL may comprise an adjuster AD configured to adjust the angular intensity distribution of the radiation beam. Generally, at least the outer and/or inner radial extent (commonly referred to as σ -outer and σ -inner, respectively) of the intensity distribution in a pupil plane of the illuminator can be adjusted. In addition, the illuminator IL may comprise various other components, such as an integrator IN, a condenser CO, a faceted field mirror device and/or a pupil mirror device. The illuminator may be used to condition the radiation beam, to have a desired uniformity and intensity distribution in its cross-section. Similar to the source SO, the illuminator IL may or may not be considered to form part of the lithographic apparatus. For example, the illuminator IL may be an integral part of the lithographic apparatus or may be a separate entity from the lithographic apparatus. In the latter case, the lithographic apparatus may be configured to allow the illuminator IL to be mounted thereon. Optionally, the illuminator IL is detachable and may be separately provided (for example, by the lithographic apparatus manufacturer or another supplier).

[00062] The radiation beam B is incident on the patterning device (e.g., mask) MA, which is held on the support structure (e.g., mask table) MT, and is patterned by the patterning device. Having traversed the patterning device MA, the radiation beam B passes through the projection system PS, which focuses the beam onto a target portion C of the substrate W. With the aid of the second positioner PW and position sensor PS1 (e.g. an interferometric device, linear encoder or capacitive sensor), the substrate table WT can be moved accurately, e.g. so as to position different target portions C in the path of the radiation beam B. Similarly, the first positioner PM and another position sensor (which is not

explicitly depicted in Figure 1) can be used to accurately position the patterning device MA with respect to the path of the radiation beam B, e.g. after mechanical retrieval from a mask library, or during a scan. In general, movement of the support structure MT may be realized with the aid of a long-stroke module (coarse positioning) and a short-stroke module (fine positioning), which form part of the first positioner PM. Similarly, movement of the substrate table WT may be realized using a long-stroke module and a short-stroke module, which form part of the second positioner PW. In the case of a stepper (as opposed to a scanner) the support structure MT may be connected to a short-stroke actuator only, or may be fixed. Patterning device MA and substrate W may be aligned using patterning device alignment marks M1, M2 and substrate alignment marks P1, P2. Although the substrate alignment marks as illustrated occupy dedicated target portions, they may be located in spaces between target portions (these are known as scribe-lane alignment marks). Similarly, in situations in which more than one die is provided on the patterning device MA, the patterning device alignment marks may be located between the dies.

[00063] The depicted apparatus could be used in at least one of the following modes:

[00064] 1. In step mode, the support structure MT and the substrate table WT are kept essentially stationary, while an entire pattern imparted to the radiation beam is projected onto a target portion C at one time (i.e. a single static exposure). The substrate table WT is then shifted in the X and/or Y direction so that a different target portion C can be exposed. In step mode, the maximum size of the exposure field limits the size of the target portion C imaged in a single static exposure.

[00065] 2. In scan mode, the support structure MT and the substrate table WT are scanned synchronously while a pattern imparted to the radiation beam is projected onto a target portion C (i.e. a single dynamic exposure). The velocity and direction of the substrate table WT relative to the support structure MT may be determined by the (de-)magnification and image reversal characteristics of the projection system PS. In scan mode, the maximum size of the exposure field limits the width (in the non-scanning direction) of the target portion in a single dynamic exposure, whereas the length of the scanning motion determines the height (in the scanning direction) of the target portion.

[00066] 3. In another mode, the support structure MT is kept essentially stationary holding a programmable patterning device, and the substrate table WT is moved or scanned while a pattern imparted to the radiation beam is projected onto a target portion C. In this mode, generally a pulsed radiation source is employed and the programmable patterning device is updated as required after each movement of the substrate table WT or in between successive radiation pulses during a scan. This mode of operation can be readily applied to maskless lithography that utilizes programmable patterning device, such as a programmable mirror array of a type as referred to above.

[00067] Combinations and/or variations on the above described modes of use or entirely different modes of use may also be employed.

[00068] Figure 7 shows the EUV apparatus 4100 in more detail, including the source collector apparatus SO, the illumination system IL, and the projection system PS. The source collector apparatus

SO is constructed and arranged such that a vacuum environment can be maintained in an enclosing structure 4220 of the source collector apparatus SO. An EUV radiation emitting plasma 4210 may be formed by a discharge produced plasma source. EUV radiation may be produced by a gas or vapor, for example Xe gas, Li vapor or Sn vapor in which the very hot plasma 4210 is created to emit radiation in the EUV range of the electromagnetic spectrum. The very hot plasma 4210 is created by, for example, an electrical discharge causing an at least partially ionized plasma. Partial pressures of, for example, 10 Pa of Xe, Li, Sn vapor or any other suitable gas or vapor may be required for efficient generation of the radiation. A plasma of excited tin (Sn) may be provided to produce EUV radiation.

[00069] The radiation emitted by the hot plasma 4210 is passed from a source chamber 4211 into a collector chamber 4212 via an optional gas barrier or contaminant trap 4230 (in some cases also referred to as contaminant barrier or foil trap) which is positioned in or behind an opening in source chamber 4211. The contaminant trap 4230 may include a channel structure. Contaminant trap 4230 may include a gas barrier or a combination of a gas barrier and a channel structure. The contaminant trap or contaminant barrier 4230 further indicated herein at least includes a channel structure, as known in the art.

[00070] The collector chamber 4212 may include a radiation collector CO which may be a so-called grazing incidence collector. Radiation collector CO has an upstream radiation collector side 4251 and a downstream radiation collector side 4252. Radiation that traverses collector CO can be reflected off a grating spectral filter 4240 to be focused in a virtual source point IF. The virtual source point IF is commonly referred to as the intermediate focus, and the source collector apparatus is arranged such that the intermediate focus IF is located at or near an opening 4221 in the enclosing structure 4220. The virtual source point IF is an image of the radiation emitting plasma 4210.

[00071] Subsequently the radiation traverses the illumination system IL, which may include a faceted field mirror device 422 and a faceted pupil mirror device 424 arranged to provide a desired angular distribution of the radiation beam 421, at the patterning device MA, as well as a desired uniformity of radiation intensity at the patterning device MA. Upon reflection of the beam of radiation 421 at the patterning device MA, held by the support structure MT, a patterned beam 426 is formed and the patterned beam 426 is imaged by the projection system PS via reflective elements 428, 430 onto a substrate W held by the substrate table WT.

[00072] More elements than shown may generally be present in illumination optics unit IL and projection system PS. The grating spectral filter 4240 may optionally be present, depending upon the type of lithographic apparatus. There may be more mirrors present than those shown in the Figures, for example there may be 1- 6 additional reflective elements present in the projection system PS than shown in Figure 7.

[00073] Collector optic CO, as illustrated in Figure 7, is depicted as a nested collector with grazing incidence reflectors 4253, 4254 and 4255, just as an example of a collector (or collector mirror). The

grazing incidence reflectors 4253, 4254 and 4255 are disposed axially symmetric around an optical axis O and a collector optic CO of this type is preferably used in combination with a discharge produced plasma source, often called a DPP source.

[00074] Alternatively, the source collector apparatus SO may be part of an LPP radiation system as shown in Figure 8. A laser LA is arranged to deposit laser energy into a fuel, such as xenon (Xe), tin (Sn) or lithium (Li), creating the highly ionized plasma 4210 with electron temperatures of several ten's of eV. The energetic radiation generated during de-excitation and recombination of these ions is emitted from the plasma, collected by a near normal incidence collector optic CO and focused onto the opening 4221 in the enclosing structure 4220.

[00075] In many lithographic apparatus a fluid, in particular a liquid for example an immersion lithographic apparatus, is provided between the final element of the projection system using a liquid supply system IH to enable imaging of smaller features and/or increase the effective NA of the apparatus. An implementation is described further below with reference to such an immersion apparatus, but may equally be embodied in a non-immersion apparatus. Arrangements to provide liquid between a final element of the projection system and the substrate can be classed into at least two general categories. These are the bath type arrangement and the so called localized immersion system. In the bath type arrangement substantially the whole of the substrate and optionally part of the substrate table is submersed in a bath of liquid. The localized immersion system uses a liquid supply system in which liquid is only provided to a localized area of the substrate. In the latter category, the space filled by liquid is smaller in plan than the top surface of the substrate and the area filled with liquid remains substantially stationary relative to the projection system while the substrate moves underneath that area. Another arrangement, to which an implementation may be directed, is the all wet solution in which the liquid is unconfined. In this arrangement substantially the whole top surface of the substrate and all or part of the substrate table is covered in immersion liquid. The depth of the liquid covering at least the substrate is small. The liquid may be a film, such as a thin film, of liquid on the substrate.

[00076] Four different types of localized liquid supply systems are illustrated in Figures 2- 5. Any of the liquid supply devices of Figures 2-5 may be used in an unconfined system; however, sealing features are not present, are not activated, are not as efficient as normal or are otherwise ineffective to seal liquid to only the localized area.

[00077] One of the arrangements proposed for a localized immersion system is for a liquid supply system to provide liquid on only a localized area of the substrate and in between the final element of the projection system and the substrate using a liquid confinement system (the substrate generally has a larger surface area than the final element of the projection system). One way which has been proposed to arrange for this is disclosed in PCT patent application publication no. WO 99/49504. As illustrated in Figures 2 and 3, liquid is supplied by at least one inlet onto the substrate, desirably along the direction of movement of the substrate relative to the final element, and is removed by at least one outlet after

having passed under the projection system. That is, as the substrate is scanned beneath the element in a -X direction, liquid is supplied at the +X side of the element and taken up at the -X side.

[00078] Figure 2 shows the arrangement schematically in which liquid is supplied via inlet and is taken up on the other side of the element by outlet which is connected to a low pressure source. The arrows above the substrate W illustrate the direction of liquid flow, and the arrow below the substrate W illustrates the direction of movement of the substrate table. In the illustration of Figure 2 the liquid is supplied along the direction of movement of the substrate relative to the final element, though this does not need to be the case. Various orientations and numbers of in-and out-lets positioned around the final element are possible, one example is illustrated in Figure 3 in which four sets of an inlet with an outlet on either side are provided in a regular pattern around the final element. Arrows in liquid supply and liquid recovery devices indicate the direction of liquid flow.

[00079] A further immersion lithography solution with a localized liquid supply system is shown in Figure 4. Liquid is supplied by two groove inlets on either side of the projection system PS and is removed by a plurality of discrete outlets arranged radially outwardly of the inlets. The inlets and outlets can be arranged in a plate with a hole in its center and through which the projection beam is projected. Liquid is supplied by one groove inlet on one side of the projection system PS and removed by a plurality of discrete outlets on the other side of the projection system PS, causing a flow of a thin film of liquid between the projection system PS and the substrate W. The choice of which combination of inlet and outlets to use can depend on the direction of movement of the substrate W (the other combination of inlet and outlets being inactive). In the cross-sectional view of Figure 4, arrows illustrate the direction of liquid flow in inlets and out of outlets.

[00080] Another arrangement which has been proposed is to provide the liquid supply system with a liquid confinement member which extends along at least a part of a boundary of the space between the final element of the projection system and the substrate table. Such an arrangement is illustrated in Figure 5. The liquid confinement member is substantially stationary relative to the projection system in the XY plane though there may be some relative movement in the Z direction (in the direction of the optical axis). A seal is formed between the liquid confinement and the surface of the substrate. In an implementation, a seal is formed between the liquid confinement structure and the surface of the substrate and may be a contactless seal such as a gas seal. Such a system is disclosed in United States patent application publication no. US 2004-0207824, which document is incorporated herein by reference in its entirety.

[00081] Figure 5 schematically depicts a localized liquid supply system with a fluid handling structure 12. The fluid handling structure extends along at least a part of a boundary of the space between the final element of the projection system and the substrate table WT or substrate W. (Please note that reference in the following text to surface of the substrate W also refers in addition or in the alternative to a surface of the substrate table, unless expressly stated otherwise.) The fluid handling

structure 12 is substantially stationary relative to the projection system in the XY plane though there may be some relative movement in the Z direction (in the direction of the optical axis). In an implementation, a seal is formed between the barrier member and the surface of the substrate W and may be a contactless seal such as a fluid seal, desirably a gas seal.

5 **[00082]** The fluid handling structure 12 at least partly contains liquid in the space 11 between a final element of the projection system PS and the substrate W. A contactless seal 16 to the substrate W may be formed around the image field of the projection system so that liquid is confined within the space between the substrate W surface and the final element of the projection system PS. The space is at least partly formed by the fluid handling structure 12 positioned below and surrounding the final
10 element of the projection system PS. Liquid is brought into the space below the projection system and within the fluid handling structure 12 by liquid inlet 13. The liquid may be removed by liquid outlet 13. The fluid handling structure 12 may extend a little above the final element of the projection system. The liquid level rises above the final element so that a buffer of liquid is provided. In an implementation, the fluid handling structure 12 has an inner periphery that at the upper end closely conforms to the shape
15 of the projection system or the final element thereof and may, e.g., be round. At the bottom, the inner periphery closely conforms to the shape of the image field, e.g., rectangular, though this need not be the case.

[00083] In an implementation, the liquid is contained in the space 11 by a gas seal 16 which, during use, is formed between the bottom of the fluid handling structure 12 and the surface of the substrate W.
20 The gas seal is formed by gas, e.g. air or synthetic air but, in an implementation, N₂ or another inert gas. The gas in the gas seal is provided under pressure via inlet 15 to the gap between fluid handling structure 12 and substrate W. The gas is extracted via outlet 14. The overpressure on the gas inlet 15, vacuum level on the outlet 14 and geometry of the gap are arranged so that there is a high- velocity gas flow 16 inwardly that confines the liquid. The force of the gas on the liquid between the fluid handling structure
25 12 and the substrate W contains the liquid in a space 11. The inlets/outlets may be annular grooves which surround the space 11. The annular grooves may be continuous or discontinuous. The flow of gas 16 is effective to contain the liquid in the space 11. Such a system is disclosed in United States patent application publication no. US 2004-0207824, which document is incorporated herein by reference in its entirety.

30 **[00084]** The example of Figure 5 is a localized area arrangement in which liquid is only provided to a localized area of the top surface of the substrate W at any one time. Other arrangements are possible, including fluid handling systems which make use of a single phase extractor or a two phase extractor as disclosed, for example, in United States patent application publication no US 2006-0038968, which document is incorporated herein by reference in its entirety.

35 **[00085]** Another arrangement which is possible is one which works on a gas drag principle. The so-called gas drag principle has been described, for example, in United States patent application

publication nos. US 2008-0212046, US 2009-0279060, and US 2009-0279062, which documents are incorporated herein by reference in its entirety. In that system the extraction holes are arranged in a shape which desirably has a corner. The corner may be aligned with the stepping or scanning directions. This reduces the force on the meniscus between two openings in the surface of the fluid handling structure for a given speed in the step or scan direction compared to if the two outlets were aligned perpendicular to the direction of scan.

[00086] Also disclosed in US 2008-0212046, which document is incorporated herein by reference in its entirety, is a gas knife positioned radially outside the main liquid retrieval feature. The gas knife traps any liquid which gets past the main liquid retrieval feature. Such a gas knife may be present in a so called gas drag principle arrangement (as disclosed in US 2008-0212046, which document is incorporated herein by reference in its entirety), in a single or two phase extractor arrangement (such as disclosed in United States patent application publication no. US 2009-0262318, which document is incorporated herein by reference in its entirety) or any other arrangement.

[00087] Many other types of liquid supply system are possible. The present invention is neither limited to any particular type of liquid supply system, nor to immersion lithography. The invention may be applied equally in any lithography. In an EUV lithography apparatus, the beam path is substantially evacuated and immersion arrangements described above are not used.

[00088] A control system 500 shown in Figure 1 controls the overall operations of the lithographic apparatus and in particular performs an optimization process described further below. Control system 500 can be embodied as a suitably-programmed general purpose computer comprising a central processing unit, volatile and non-volatile storage means, one or more input and output devices such as a keyboard and screen, one or more network connections and one or more interfaces to the various parts of the lithographic apparatus. It will be appreciated that a one-to-one relationship between controlling computer and lithographic apparatus is not necessary. In an implementation one computer can control multiple lithographic apparatuses. In an implementation, multiple networked computers can be used to control one lithographic apparatus. The control system 500 may also be configured to control one or more associated process devices and substrate handling devices in a lithocell or cluster of which the lithographic apparatus forms a part. The control system 500 can also be configured to be subordinate to a supervisory control system of a lithocell or cluster and/or an overall control system of a fab.

[00089] Figure 9 depicts a substrate holder 100 according to an implementation. It may be held within a recess in substrate table WT and supports substrate W. The main body of the substrate holder 100a, in an embodiment, is substantially flat and corresponds in shape and size to the substrate W, e.g., a flat plate, for example a disc. At least on a top side, in an embodiment on both sides, the substrate holder has projections 106 (i.e. burls), commonly referred to as burls. In an embodiment, the substrate holder is an integral part of the substrate table and does not have burls on the lower surface. The burls are not shown to scale in Figure 9. In a practical embodiment, there can be many hundreds, thousands,

or tens of thousands, of burls distributed across a substrate holder of diameter, e.g., 200 mm, 300 mm or 450 mm. The tips of the burls have a small area, e.g. less than 1 mm^2 , so that the total area of all of the burls on one side of the substrate holder 100 is less than about 10% of the total area of the total surface area of the substrate holder. Because of the burl arrangement on the support, there is a high probability that any particle that might lie on the surface of the substrate, substrate holder or substrate table will fall between burls and will not therefore result in a deformation of the substrate or substrate holder. The burl arrangement, which may form a pattern, can be regular or can vary as desired to provide appropriate distribution of force on the substrate and substrate table. The burls can have any shape in plan but are commonly circular in plan. The burls can have the same shape and dimensions throughout their height but are commonly tapered. The projections (i.e. burls) can project a distance of from about $1 \text{ }\mu\text{m}$ to about 5 mm, desirably from about $5 \text{ }\mu\text{m}$ to about 250 μm , from the rest of the surface of the main body 100a of the substrate holder 100. The thickness of the main body 100a of the substrate holder 100 can be in the range of about 1 mm to about 50 mm, desirably in the range of about 5 mm to 20 mm, typically 10 mm.

[00090] The substrate holder 100 may be made of rigid material. Desirably the material has a high thermal conductivity or a low coefficient of thermal expansion. A suitable material includes SiC (silicon carbide), SiSiC (siliconised silicon carbide), Si_3N_4 (silicon nitride), quartz, and/or various other ceramic and glass- ceramics, such as ZerodurTM glass ceramic. The substrate holder 100 can be manufactured by selectively removing material from a solid disc of the relevant material so as to leave the projecting burls. A suitable technique to remove material includes electrical discharge machining (EDM), etching, machining and/or laser ablation. The substrate holder can also be manufactured by growing burls through a mask. The burls may be of the same material as the base and can be grown by a physical vapor deposition process or sputtering.

[00091] In an implementation, a substrate holder comprises one or more electrodes for an electrostatic clamp. A potential difference may be generated between electrodes in order to provide an electrostatic clamping force between the substrate W and the substrate holder 100 and/or between the substrate holder 100 and the substrate table WT. In an embodiment, the electrodes are encapsulated between electrical isolation layers. The potential difference generated between the electrodes may be of the order of 10 to 5,000 volts. Arrangements using one or more heaters and temperature sensors to locally control the temperature of a substrate are described in U.S. publication no. 2011-0222033, which is incorporated herein by reference in its entirety and the techniques therein may be applied to the techniques herein.

[00092] In the description above referring to Figure 9, reference is made to an implementation including a substrate holder 100 mounted on a substrate table WT. However, the description is equally applicable to equivalent implementations in which a patterning device holder 100 is provided in place of the substrate holder 100 and a support structure MA for a patterning device is provided in place of

the substrate table WT. Furthermore, the description is equally applicable to any object holder for supporting an object for use in a lithographic apparatus.

5 [00093] For the electrodes of an electrostatic clamp, two halves of continuous metal film (but isolated from the end surfaces of the burls) may be separated by approximately 500 μm from each other and deposited to form positive and negative elements of the electrostatic clamp. There may therefore be two electrodes. Metal lines of the electrodes may have a layer thickness greater than about 20 nm, desirably greater than about 40 nm. The metal lines desirably have a layer thickness less than or equal to about 1 μm , desirably less than about 500 nm, desirably less than about 200 nm.

10 [00094] An upper electrode layer may be configured to electrostatically clamp the object, such as a substrate W, to the object holder and a lower electrode layer may be configured to electrostatically clamp the object holder to a supporting structure for the object holder, which may be referred to as an object table or just a table. The table may be a substrate table WT for supporting a substrate holder, for example. The table may alternatively be a supporting structure MT for supporting a patterning device holder, for example.

15 [00095] One or more electrodes electrostatically clamp an object (e.g. a substrate or patterning device) to be supported by the object holder against burls on a surface of the object holder. The object is held in contact with the distal ends of the burls. Alternatively or additionally, one or more electrodes may be provided to electrostatically clamp the object holder to a table (e.g. a substrate table or support structure for a patterning device) that is adapted to support the object holder. The object table is held in
20 contact with the distal ends of the burls on a surface of the object holder.

[00096] A grounding layer may be provided that electrically connects two or more of the burls (optionally all of the burls) to ground or a common electrical potential. The grounding layer may be formed by depositing a relatively thick layer of CrN. The deposited layer is then patterned to form the grounding layer. The pattern may comprise a series of metal lines that connect together distal ends of
25 the burls. Such patterns are sometimes referred to as "Manhattan" patterns.

[00097] The above-described techniques are known and described in at least WO2014/154428A2, the entire contents of which are incorporated herein by reference.

[00098] As described above, object holder may be both electrostatically clamped to a table for the object holder and/or an object may be electrostatically clamped to the object holder.

30 [00099] Figure 10 shows a cross section through part of a known object holder when a lower surface of the object holder is clamped to a table 1012 and an object 1001 is clamped to the upper surface of the object holder. The object may be a substrate or a patterning device, as described earlier. The table may be a substrate table or mask table as described earlier.

[000100] As shown in Figure 10, the object holder comprises a core layer 1006. Below the core layer
35 1006 is a first insulation layer 1008. Below the first insulation layer 1008 is a first electrode layer 1009. Below the first electrode layer 1009 is a first dielectric layer 1010. Above the core layer 1006 is a second

insulation layer 1005. Above the second insulation layer 1005 is a second electrode layer 1004. Above the second electrode layer 1004 is a second dielectric layer 1003.

[000101] A plurality of burls 1011 are provided on the lower surface of the object holder. A metal layer is provided at the end of each burl 1011 that protrudes from the lower surface of the object holder.

5 A plurality of burls 1002 are also provided on the upper surface of the object holder. A metal layer is provided at the end of each burl 1002 that protrudes from the upper surface of the object holder.

[000102] The burl 1011 on the lower surface is a long burl. The burl 1002 on the upper surface is a short burl.

[000103] As shown in Figure 10, a long burl 1011 has a trench 1007 around it. The trench 1007 may
10 extend from the lower surface of the object holder into the core layer 1006. The trench 1007 increases the distance between the distal end and the base of the long burl 1011. The provision of the trench allows, to a certain extent, the distal end of each long burl 1011 to move laterally, i.e. parallel to the upper and lower surfaces of the object holder. The lateral movement of the end of each long burl 1011 helps to prevent slippage occurring between the object holder and the table. Such slippage should be
15 prevented because it is a cause of overlay errors.

[000104] As shown in Figure 10, a trench is not provided around a short burl 1002.

[000105] The lower surface comprises both long burls 1011 and short burls. Provided on the lower surface are metal lines, or tracks, that are arranged in circular arcs and Manhattan patterns. The metal lines that connect the short burls to each other and to the Manhattan patterns are circular arcs. The
20 Manhattan patterns comprise the metal lines that are provided around the long burls, the metal lines connected between these parts, and the metal lines connected to the perimeter of the object holder.

[000106] Figure 11A shows some of the metal lines of Manhattan patterns on the lower surface of the object holder in more detail.

[000107] Figure 11B shows the structures in the first electrode layer 1009 within the object holder.
25 The first electrode layer 1009 also comprises metal lines in Manhattan patterns.

[000108] Figure 11C shows a cross-section through the object holder, in a plane orthogonal to the lower surface of the object holder, along lines A to A* in Figures 11A and 11B.

[000109] The purpose of the metal lines in Manhattan patterns, as shown in Figures 11A and 11B, is so that the end of each long burl 1011 that contacts the table is substantially at the ground potential.
30 This is done by holding the surrounding part of the trench of each burl, referred to herein as the burl electrode, at the ground potential. As shown in Figures 11A and 11B, the metal lines connect the burl electrode around each long burl 1011 to the outer perimeter of the object holder. The connection to the outer perimeter may be via a plurality of burl electrodes of long burls 1011. The outer perimeter of the object holder is at a ground potential and so the burl electrodes of the long burls 1011 are also at the
35 ground potential.

[000110] The first electrode layer 1009, as shown in Figure 11B, comprises metal lines in Manhattan patterns that connect each burl electrode to ground. The first electrode layer 1009 also comprises one or more clamping electrodes of the electrostatic clamp that clamps the object holder to the table. The metal lines of clamping electrodes are separated from the metal lines of the ground connections, by insulating parts, so that the clamping electrodes are not connected to ground. The insulating parts may just be an gap between the clamping electrodes and the ground connections or any of a number of types of known insulator may be used to isolate the clamping electrodes from the ground connections.

[000111] The short burls on the lower surface of the object holder are held at ground by the metal lines on the lower surface of the object holder between the short burls and to the Manhattan patterns.

[000112] The electrostatic clamping between the upper surface of the object holder and the object is by the one or more second clamping electrodes in the second electrode layer 1004. Only short burls 1002 are provided on the upper surface of the object holder. Metal lines between the short burls 1002 on the upper surface and to the perimeter of the upper surface are provided so that the ends of short burls 1002 that contact the object are connected to ground.

[000113] The known object holder shown in Figure 10 effectively comprises two separate electrostatic clamps. A first electrostatic clamp holds the object holder to the table and a second electrostatic clamp holds an object to the object holder.

[000114] A problem with the above-described known object holder is that the metal lines that provide the ground connections reduce the clamping efficiency because there is no clamping force where the metal lines of the ground connections are provided on the upper and lower surfaces of the object holder. In particular, the use of long burls 1011 significantly reduces the clamping efficiency because of the relatively large surface area required by the long burls 1011 and the ground connections that are provided by metal lines in Manhattan patterns. Accordingly, the number of long burls 1011 that are provided on the lower surface of the above-described known design of object holder is restricted because the clamping efficiency decreases when the number of long burls 1011 increases.

[000115] Another problem experienced by the above-described known design of object holder that the metal lines in Manhattan patterns can increase the amount of surface residual charge. Surface residual charge can be caused by surface leakage and/or cycle induced charging (CIC), both of which are related to the use of metal lines in Manhattan patterns. When there is a large build-up of residual charge, the residual charge may prevent the object holder being removed from the table. When this happens, it may be necessary to stop the operation of the lithographic apparatus so that it can be opened and the object holder removed from the table by other techniques. The downtime of this may be up to eleven hours, in particular for an EUV apparatus because it is necessary to restore vacuum conditions.

[000116] Embodiments provide a new object holder that does not experience at least some of the problems experienced by known object holders. Embodiments improve on the known design of object holder by reducing the effect of clamping efficiency decreasing when the number of long burls is

increased. Embodiments may also reduce the amount of residual charge build up on the surfaces of an object holder.

[000117] With the above-described known design of object holder, it is not possible to only use long burls on the lower surface because of the resulting decrease in clamping efficiency. Both long and short burls are therefore used on the lower surface. The different types of burls are positioned in dependence on a specific motor positioning for the table that the object holder is designed to clamp to.

[000118] With the object table according to embodiments, only long burls may be used on the lower surface. The long burls may be uniformly distributed over the lower surface (i.e. for a circular object holder, the long burls may be provided in a plurality of concentric circles with the axial spacing of the long burls in each concentric circle being substantially constant). This provides improved performance over the above-described known design of object table in which short burls are used on the lower surface and the clamping force is not uniform. The object holder according to embodiments is also versatile because it may be used with any number of motors, and positioning of the motors, for the table that the object holder is clamped to.

[000119] Figures 12A, 12B, 12C, 13 and 14 show how long burls may be provided on the lower surface of an object holder according to an embodiment. The object holder may comprise a core layer 1006, a first insulation layer 1008, a first electrode layer 1009, a first dielectric layer 1010, a second insulation layer 1005, a second electrode layer 1004, a second dielectric layer 1003 in a layered arrangement as described earlier, with reference to at least Figure 10, for the known design of object holder. In embodiments, each of the layers may be made of the same materials according to the known design of object holder.

[000120] The object holder according to embodiments differs from the known design of object holder by not comprising metal lines in Manhattan patterns on the lower surface and in the first electrode layer 1009 of the object holder. Each long burl has a burl electrode 1304 surrounding the trench 1303 in the first electrode layer 1009. The burl electrode 1304 is separated from a clamping electrode 1301 by an insulating part 1302. The burl electrode 1304 is connected to ground by one or more electrically conducting vias 1305 that are connected at one end to the burl electrode 1304 in the first electrode layer 1009 and at the other end to the core layer 1006 of the object holder. The core layer 1006 of the object holder is at the ground potential.

[000121] A difference between the object holder according to embodiments and the known design of object holder, is that the burl electrode 1304 according to embodiments is not directly connected to the perimeter of the object holder by metal lines in Manhattan patterns in the first electrode layer 1009. In embodiments, there are also no metal lines in Manhattan patterns on the lower surface of the object holder.

[000122] Figure 12A shows the ends of burl bodies of long burls according to an embodiment in which there are no metal lines on the lower surface of the object holder that provide a ground connection to the perimeter of the object holder.

5 [000123] Figure 12B shows part of the first electrode layer 1009 according to an embodiment in which the burl electrodes of long burls are not directly connected in the first electrode layer 1009 to the perimeter of the object holder. The first electrode layer comprises, for each long burl, a trench 1303 that surrounds a burl body, a burl electrode 1304 that surrounds the trench 1303, an insulating part 1302 that surrounds each burl electrode 1304 and one or more clamping electrodes 1301 that surround the insulating part 1302.

10 [000124] Figure 12C shows a cross-section through a long burl according to an embodiment, in a plane orthogonal to the lower surface of the object holder, along lines A to A* in Figures 12A and 12B. The first electrode layer comprises, for each long burl, a trench 1303 that surrounds a burl body, a burl electrode 1304 that surrounds the trench 1303, an insulating part 1302 that surrounds each burl electrode 1304 and one or more clamping electrodes 1301 that surround the insulating part 1302. Vias 1305 are
15 provided between the burl electrode 1304 in the first electrode layer 1009 and the core layer 1006. A metal layer 1306 may be provided at the distal end of each long burl.

[000125] Figure 13 shows a cross-section through a long burl according to an embodiment.

[000126] Figure 14 is a view of the first electrode layer 1009 of a long burl on the lower surface of an object holder according to an embodiment. In Figure 14, two vias 1305 connect the burl electrode
20 1304 of the long burl to the core layer 1006. However, embodiments also include just one via 1305 being connected to the burl electrode 1304 or more than two vias 1305 being connected to the burl electrode 1304.

[000127] A number of known techniques may be used to provide each via 1305 through the first insulation layer 1008. For example, each via 1305 may be etched or laser drilled. When metal is
25 deposited to form the metal in the first electrode layer 1009, the metal will also be deposited onto the side walls of each via 1305 and thereby form an electrical connection to the core layer 1006.

[000128] Embodiments also include providing one or more vias that are connected at one end to the metal layer 1306 at the distal end of the burl body of each long burl and connected at their other end to the core layer 1006. The end of the long burl that contacts the table is thereby directly connected to
30 ground by the vias 1305 through the central body of the long burl.

[000129] Embodiments increase the clamping efficiency over the above-described known design of electrostatic clamp. For the known design of electrostatic clamp, the provision of features on the lower surface reduces the clamping efficiency from if there were no features on the lower surface to about 92.0%. For the electrostatic clamp of the above-described embodiment, the features on the lower surface
35 reduce the clamping efficiency from if there were no features on the lower surface to about 93.8%. The

electrostatic clamp according to embodiments therefore improves on the known design of electrostatic clamp by having a higher clamping efficiency.

[000130] The effect of residual charge is also reduced because there are no metal lines in Manhattan patterns.

5 **[000131]** In addition, only long burls are provided on the lower surface and this allows more versatile operation, increased relative movement between the support structure and the table, and a more uniform clamping force.

[000132] Figures 15 and 16 show short burls 1603 that may be provided on the upper surface of the object holder according to embodiments. The object holder comprises an electrostatic clamp for
10 clamping an object to the upper surface of the object holder. One or more electrically conducting vias 1602 are provided for connecting the ends of each of the short burls 1603 to the grounded core layer 1006.

[000133] In the implementation of an embodiment shown in Figure 15, a via 1602 passes through the body of a short burl 1603 and directly connects to the metal layer 1601 on the end surface of the
15 short burl 1603.

[000134] In the implementation of an embodiment shown in Figure 16, the metal layer 1601 on the end surface of a short burl 1603 is connected to a metal layer on the sidewalls of the short burl 1603 and a metal layer around the base of the short burl 1603. Each via 1602 is connected to the metal layer around the base of the short burl 1603 and the vias 1603 do not extend through the body of each short
20 burl 1603. The metal layer 1601 on the end surface of each short burl 1603 is grounded because of the electrical connection between the metal layer around the base, the metal layer on the sidewalls and the metal layer on the end surface of each short burl 1603.

[000135] In the embodiments shown in Figures 15 and 16, the part of each via 1602 that passes through the second conducting layer 1004 is surrounded by an insulating part 1604 so that the via 1602
25 is not electrically connected to an electrode 1605 of the electrostatic clamp for clamping an object to the upper surface of the object holder.

[000136] In the embodiments shown in Figures 15 and 16, there are no metal lines on the upper surface of the object holder connecting the short burls 1603 to each other and to the grounded perimeter of the upper surface. This reduces the amount of metal lines on the upper surface and thereby reduces
30 the amount of residual charge build-up. The clamping efficiency may also be improved.

[000137] The materials used to make all of the parts of an object holder according to embodiments may be any of the known materials used to manufacture known object holders. In particular, parts of the object holder according to embodiments may be manufactured with materials as disclosed in WO2015/120923A1, WO2014/154428A2 and US2013/0094009A1, the entire contents of which are
35 incorporated herein by reference.

[000138] In particular, the metal used for the electrodes in the first electrode layer 1009 and the second electrode layer 1004 may be Cr or Ti. The metal used on the distal end surfaces of the burls may be CrN or TiN. The insulating parts between the clamping electrodes and the burl electrodes, and the clamping electrodes and vias, may be chrome oxide. The core layer 1006 may be SiSiC. The first
5 insulation layer 1008 and the second insulation layer 1005 may be a glass, such as Borofloat®. The vias may be made from Tungsten combined with Borofloat®, for example. The via diameter may be a low as 50µm.

[000139] The number of long burls may be tens of thousands. The number of short burls may be tens of thousands.

10 [000140] The dimensions of the object holder and its features (such as burls, trenches, electrode spacing and elevation pins) according to embodiments may be substantially the same as for known object holders and disclosed in the above documents that are incorporated herein by reference. Embodiments also include reducing the size of features on the upper and lower surfaces of an object holder from the size of features according to known techniques. The reduction in feature size increases
15 the clamping efficiency.

[000141] Embodiments include a number of modifications and variations to the implementations of embodiments as described above.

[000142] The object holder may be any type of a support structure that comprises one or more electrostatic clamps.

20 [000143] To aid clear explanation, embodiments have been described with reference to upper and lower surfaces of an object holder. The upper and lower surfaces are first and second surfaces of the object holder. The first surface is a surface to which an object may be clamped to. The second surface is a surface that a table may be clamped to. When the object holder is orientated in a horizontal plane, the first surface is an upper surface and the second surface is a lower surface. However, embodiments
25 also include the object holder not being orientated in a horizontal plane.

[000144] Embodiments include an object holder that comprises long burls and/or short burls according to embodiments and long burls and/or short burls provided according to known techniques.

[000145] Preferably the object holder only has long burls on the lower surface. However, the object holder may comprise a mixture of short and long burls on its lower surface.

30 [000146] The techniques according to embodiments may also be used to ground other features on the surfaces of an object holder. For example, the techniques may be used to ground elevation pins.

[000147] The ground potential may be 0V or any other voltage.

[000148] Embodiments include the object holder being used in any lithographic apparatus. The lithographic apparatus may include any apparatus used in substrate manufacture, testing and inspection,
35 such as an electron-beam inspection apparatus.

[000149] Although specific reference may have been made above to the use of embodiments of the invention in the context of object inspection and optical lithography, it will be appreciated that the invention, where the context allows, is not limited to these contexts and may be used in other applications, for example imprint lithography.

5 [000150] Where the context allows, embodiments of the invention may be implemented in hardware, firmware, software, or any combination thereof. Embodiments of the invention may also be implemented as instructions stored on a machine-readable medium, which may be read and executed by one or more processors. A machine-readable medium may include any mechanism for storing or transmitting information in a form readable by a machine (e.g., a computing device). For example, a
10 machine-readable medium may include read only memory (ROM); random access memory (RAM); magnetic storage media; optical storage media; flash memory devices; electrical, optical, acoustical or other forms of propagated signals (e.g. carrier waves, infrared signals, digital signals, etc.), and others. Further, firmware, software, routines, instructions may be described herein as performing certain actions. However, it should be appreciated that such descriptions are merely for convenience and that
15 such actions in fact result from computing devices, processors, controllers, or other devices executing the firmware, software, routines, instructions, etc. and in doing that may cause actuators or other devices to interact with the physical world.

[000151] 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
20 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 object holder arranged to support an object (1001), the object holder comprising at least a core layer (1006) and an electrode layer (1009);

5 wherein the object holder has a surface that is arranged to be clamped, by an electrostatic clamp, to a table (1012) for the object holder;

wherein, the object holder comprises a plurality of burl arrangements with each burl arrangement comprising a burl body, a trench (1303), a burl electrode (1304) and an insulating part (1302);

10 wherein, for each burl arrangement, part of the burl body protrudes from said surface of the object holder, the trench (1303) surrounds the burl body in a plane that is parallel to said surface of the object holder, the trench (1303) extends, in a direction that is orthogonal to said surface of the object holder, from said surface of the object holder to at least through the electrode layer (1009), the burl electrode (1304) is comprised by the electrode layer (1009) and surrounds the trench (1303), and the insulating part (1302) is comprised by the electrode layer (1009) and surrounds the burl electrode (1304);

15 wherein the electrode layer (1009) further comprises one or more clamping electrodes (1301) that are electrodes of the electrostatic clamp that is arranged to clamp said surface to a table (1012) for the object holder, and, within the electrode layer (1009), each of the insulating parts (1302) of a burl arrangement is surrounded by a clamping electrode (1301); and

20 wherein the object holder comprises one or more electrically conducting vias (1305) arranged between each burl electrode (1304) and the core layer (1006).

2. The object holder according to claim 1, wherein the object holder further comprises at least an insulation layer (1008) and a dielectric layer (1010);

25 wherein the insulation layer (1008) is arranged between the core layer (1006) and the electrode layer (1009);

the dielectric layer (1010) is arranged between the electrode layer (1009) and said surface of the substrate;

and, for each burl arrangement, the trench (1303) extends through the dielectric layer (1010) and the insulation layer (1008).

30

3. The object holder according to any preceding claim, wherein, for each burl arrangement, the trench (1303) extends into at least part of the core layer (1006).

4. The object holder according to any preceding claim, wherein, for each burl arrangement, the burl body comprises a metal layer (1306) at the end of the part of the burl body that protrudes from the surface.

35

5. The object holder according to claim 4, wherein each burl arrangement further comprises one or more electrically conducting vias (1305) arranged between said metal layer and the core layer (1006).

6. The object holder according to any preceding claim, wherein the electrode layer (1009) comprises two clamping electrodes (1301).

7. The object holder according to any preceding claim, wherein the core layer (1006) is at a ground potential.

8. The object holder according to any preceding claim, wherein said surface is circular and the plurality of burl arrangements are positioned on said surface with a substantially uniform axial distribution.

9. The object holder according to any preceding claim, wherein the object (1001) is a substrate or a patterning device.

10. A object holder for supporting an object (1001), the object holder comprising at least a core layer (1006) and an electrode layer (1004);

wherein the object holder has a surface that is arranged to be clamped, by an electrostatic clamp, to the object (1001);

wherein, the object holder comprises a plurality of burl arrangements;

wherein each burl arrangement comprises a burl body and a burl electrode (1601);

wherein, for each burl arrangement, an end of the burl body provides a raised part of said surface of the object holder and the burl electrode (1601) is arranged on at least the end of the burl body that provides the raised part;

wherein the electrode layer (1004) comprises one or more clamping electrodes (1605) that are electrodes of the electrostatic clamp that is arranged to clamp said surface to an object (1001);

wherein the object holder comprises one or more electrically conducting vias (1602) that extend between each burl electrode (1601) and the core layer (1006); and

wherein the electrode layer (1004) comprises a plurality of insulating parts (1604) that are arranged such that the part of each via (1602) that passes through the electrode layer (1004) is surrounded by an insulating part (1604).

11. The object holder according to claim 10, wherein the object holder further comprises at least an insulation layer (1005) and a dielectric layer (1003);

wherein the insulation layer (1005) is arranged between the core layer (1006) and the electrode layer (1004); and

wherein the dielectric layer (1003) is arranged between the electrode layer (1004) and said surface of the substrate; and

5 each via (1602) extends through the dielectric layer (1003) and the insulation layer (1005).

12. The object holder according to claim 10 or 11, wherein, for each burl arrangement, the burl electrode (1601) is further provided on side walls of the burl body and, in a plane parallel to said surface, around the base of the burl body.

10

13. The object holder according to claim 12, wherein each via (1602) is attached at one end to the part of a burl electrode (1601) that is provided around the base of each burl body.

14. The object holder according to any of claims 10 to 13, wherein the electrode layer (1004) comprises two clamping electrodes (1605).

15

15. The object holder according to any of claims 10 to 14, wherein the core layer (1006) is at a ground potential.

16. The object holder according to any of claims 10 to 15, wherein the object (1001) is a substrate or a patterning device.

20

17. A object holder arrangement for supporting an object (1001), the object holder arrangement comprising:

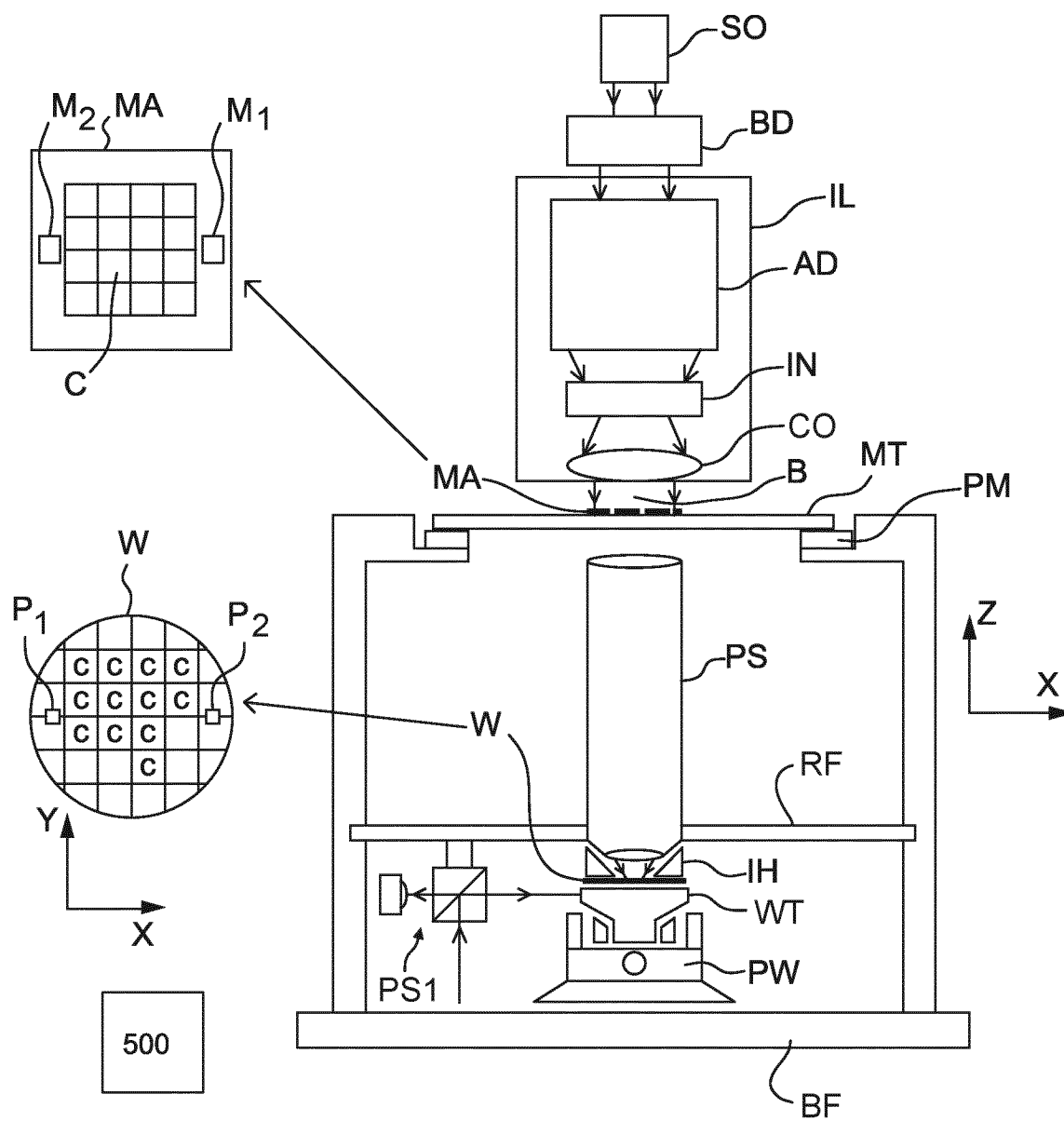
25 an object holder according to any of claims 1 to 9 arranged to electrostatically clamp the object holder to a table (1012) for the object holder; and/or

an object holder according to any of claims 10 to 16 arranged to electrostatically clamp an object (1001) to the object holder.

18. A lithographic apparatus comprising an object holder arrangement according to claim 17.

30

Fig. 1



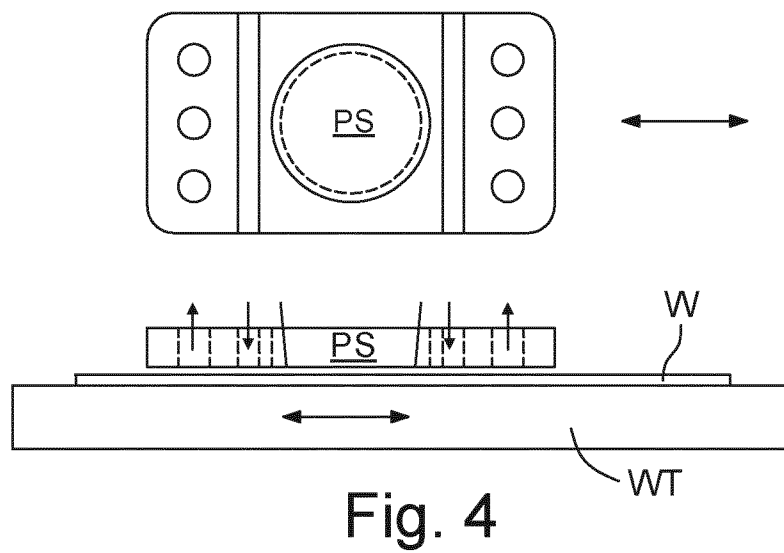
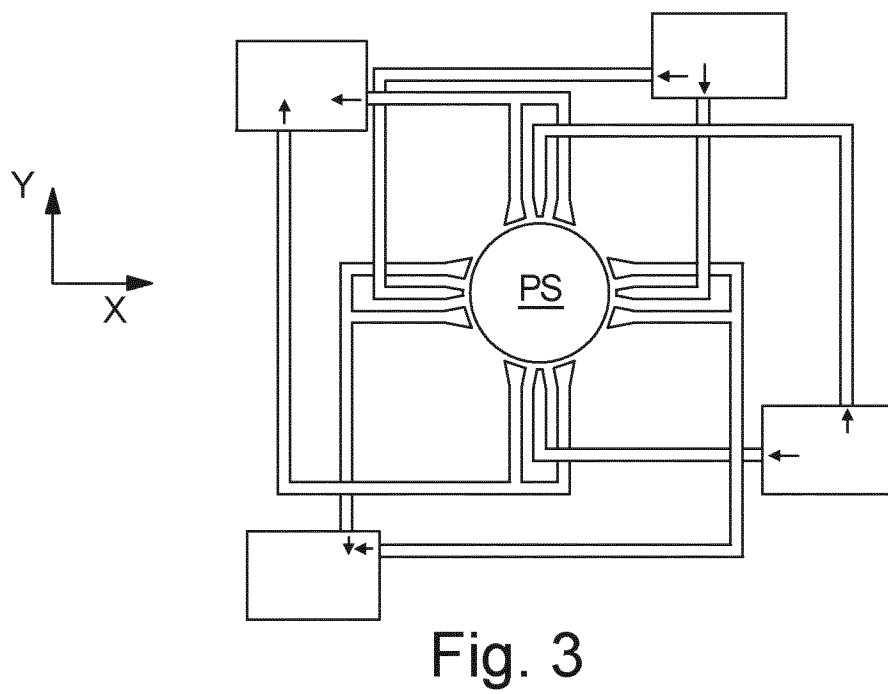
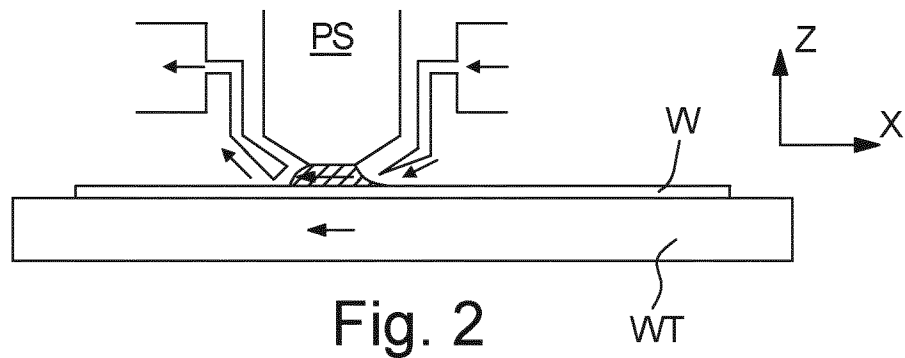


Fig. 5

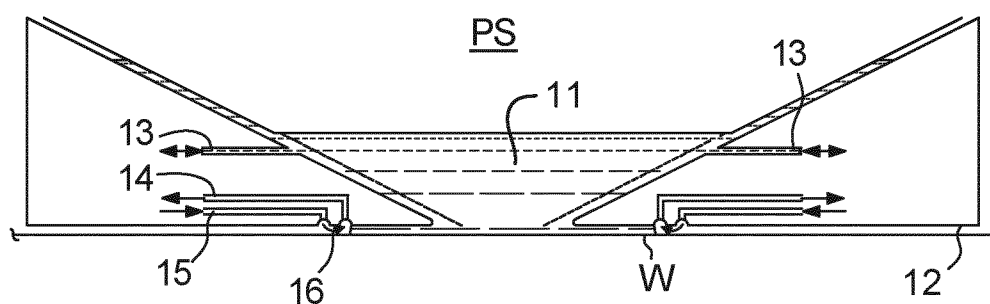


Fig. 6

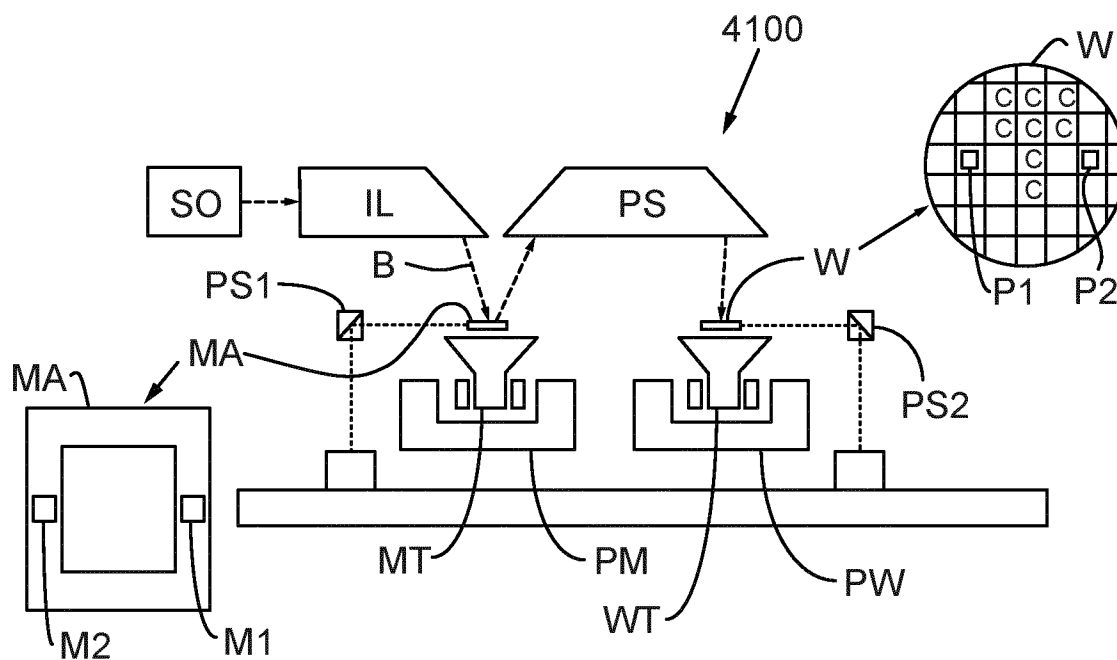


Fig. 7

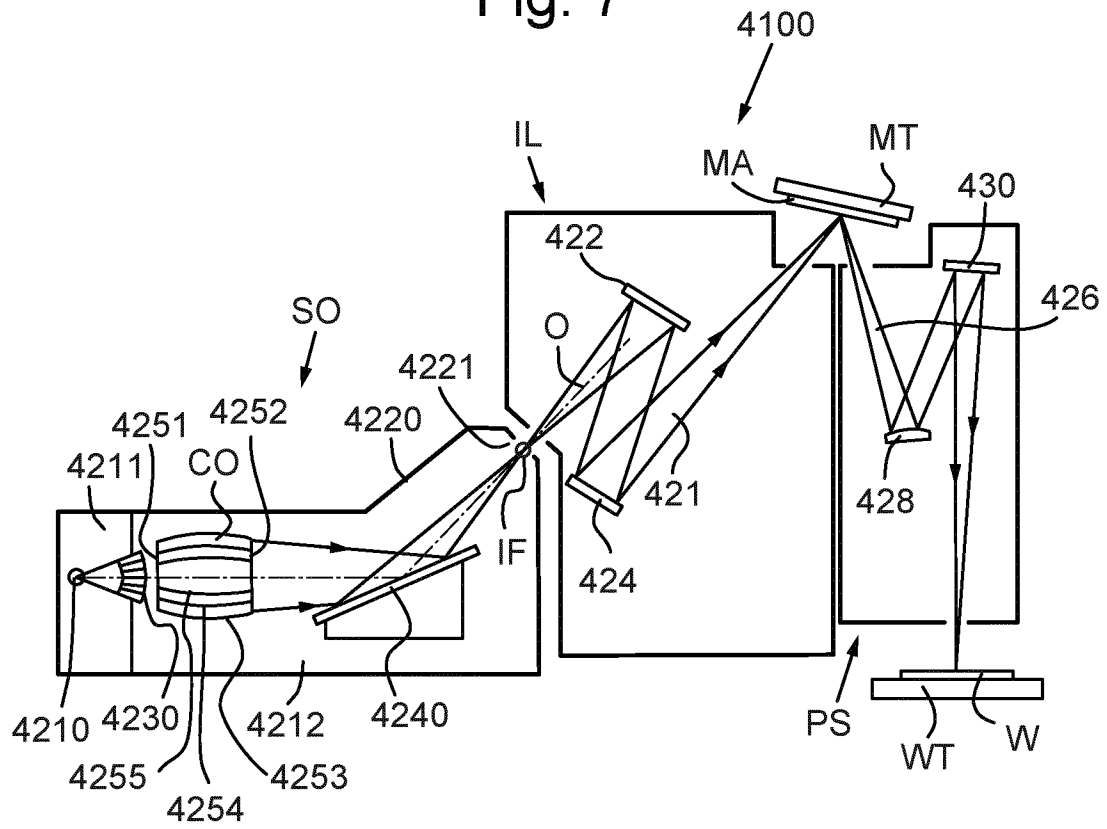


Fig. 8

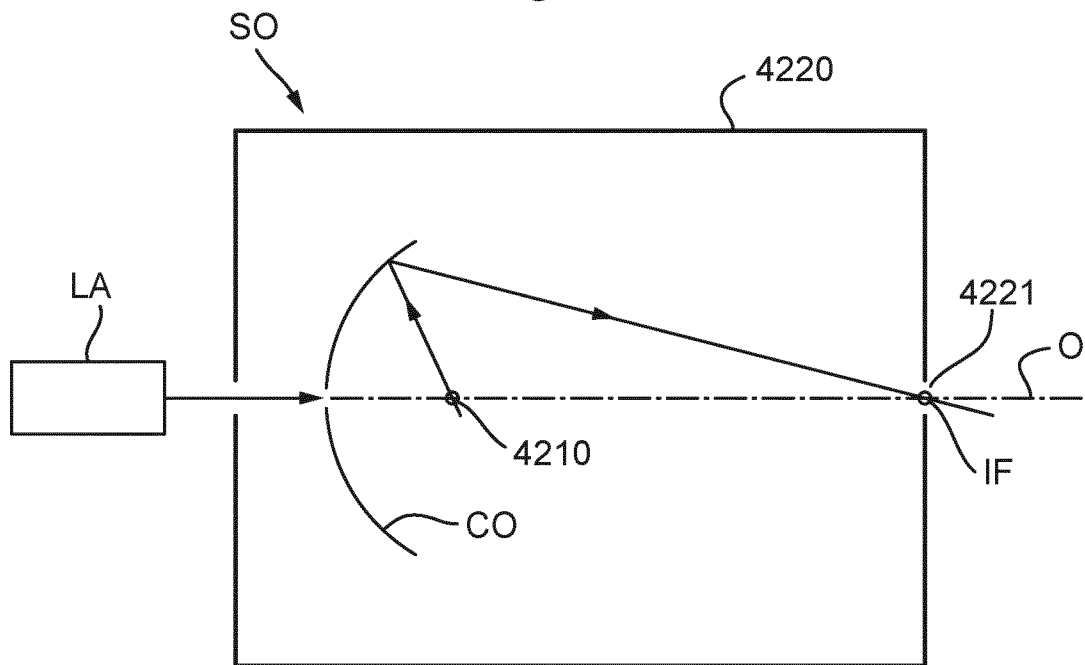


Fig. 9

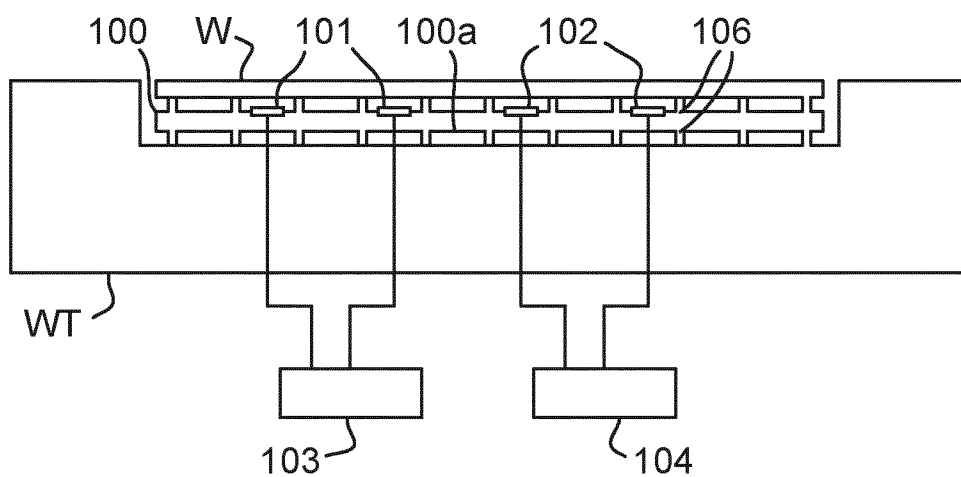


Fig. 10

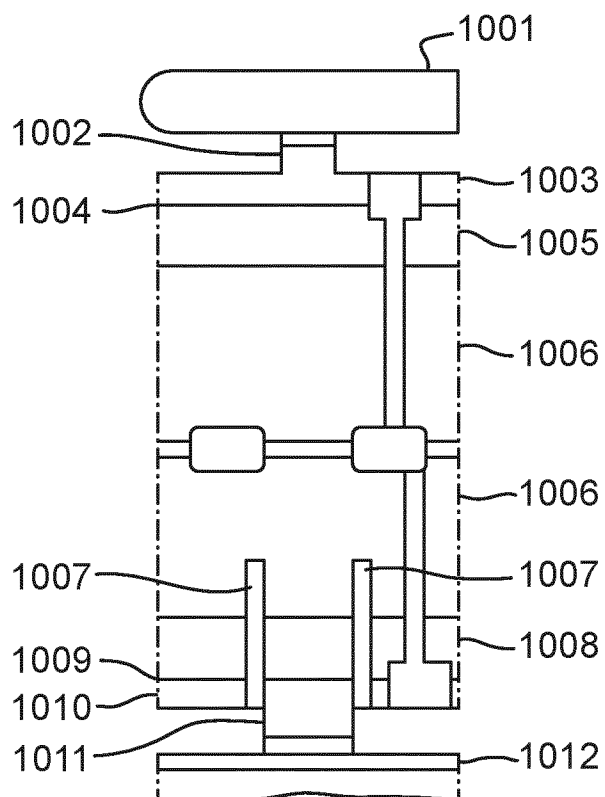


Fig. 11A

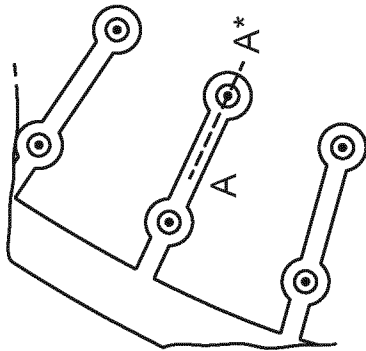


Fig. 11B

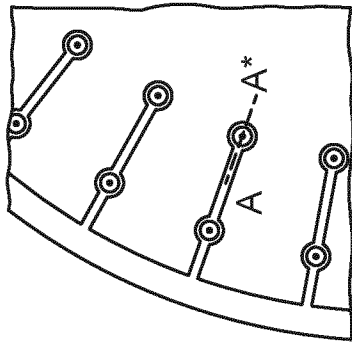


Fig. 11C

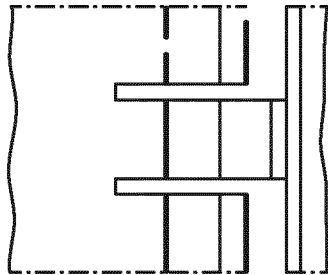


Fig. 12A

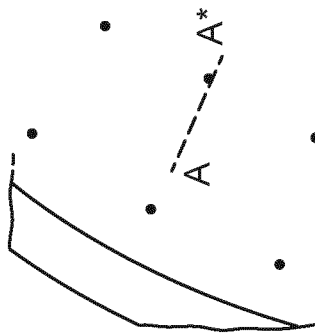


Fig. 12B

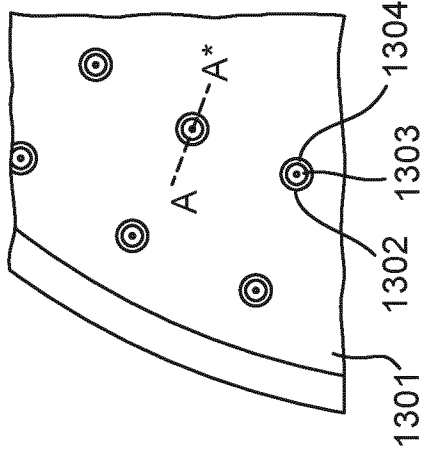


Fig. 12C

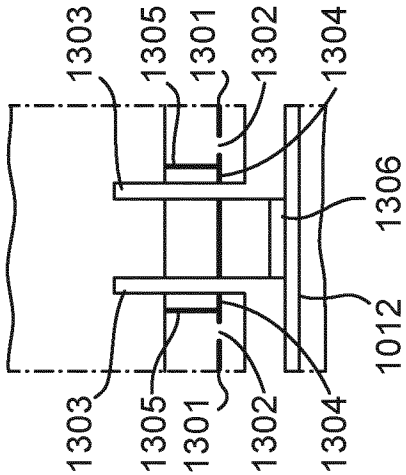


Fig. 13

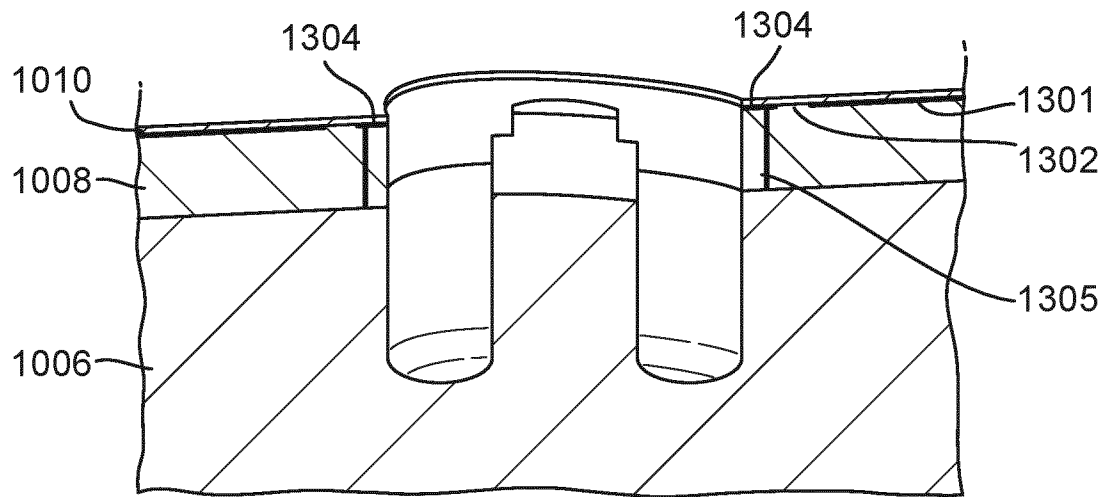


Fig. 14

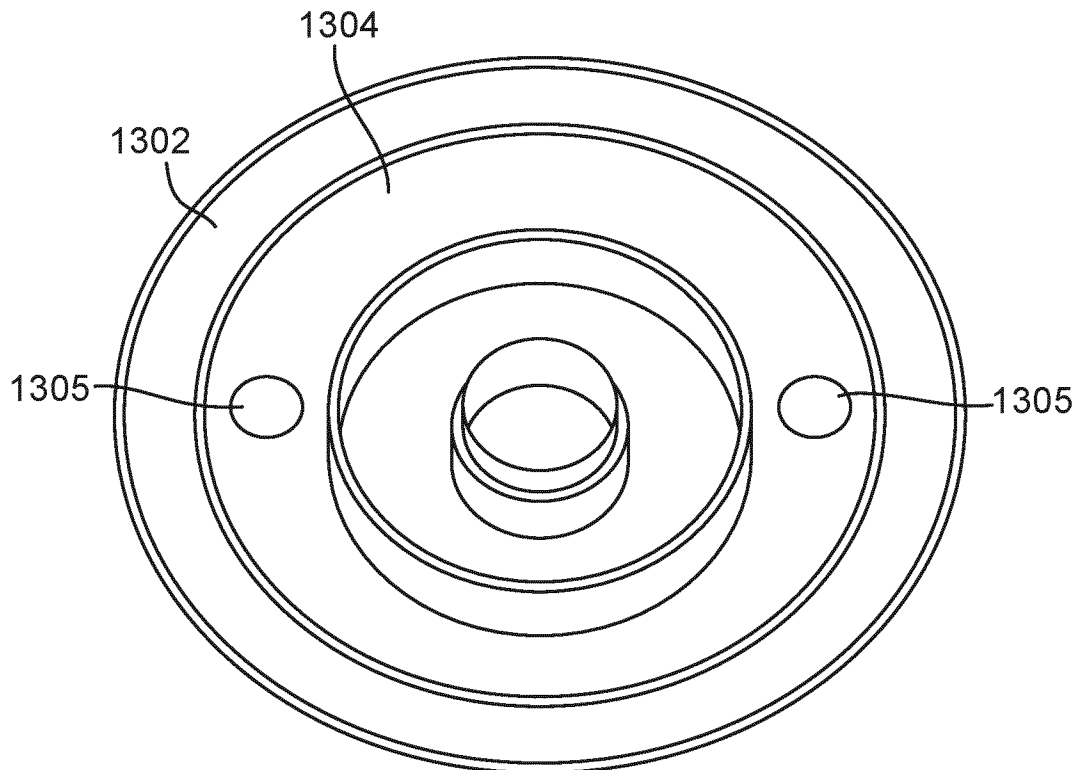


Fig. 15

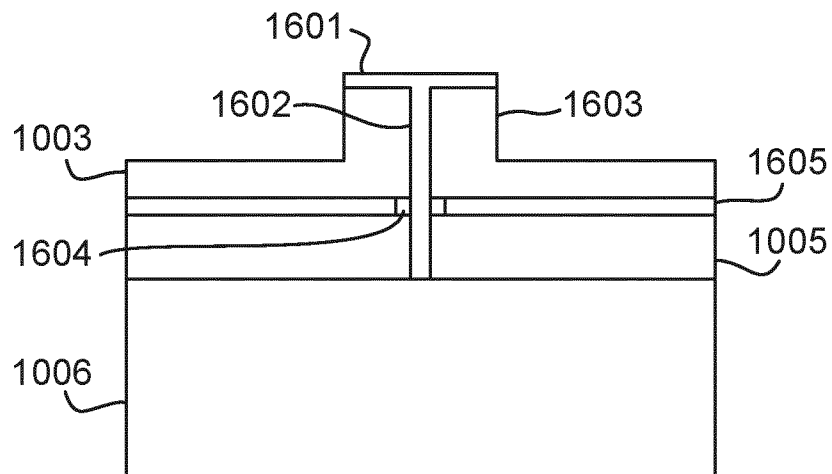
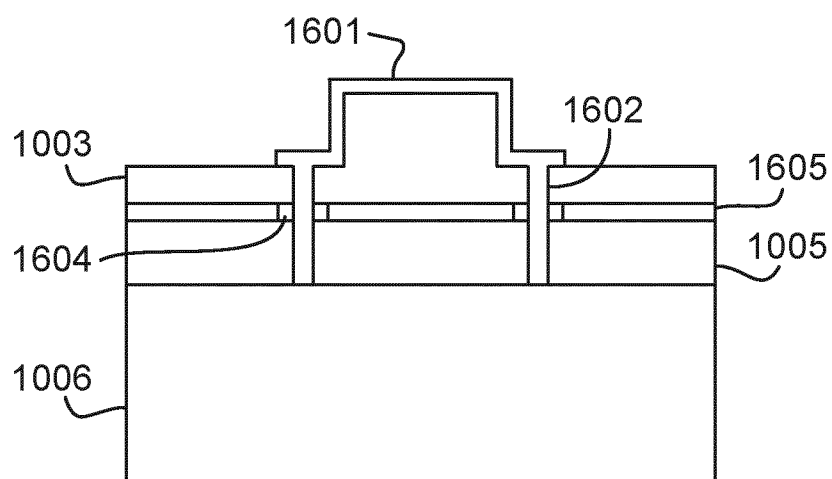


Fig. 16



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2020/052945

A. CLASSIFICATION OF SUBJECT MATTER
INV. G03F7/20 H01L21/683
ADD.

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

B. FIELDS SEARCHED

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

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2013/113568 A2 (ASML NETHERLANDS BV) 8 August 2013 (2013-08-08)	10-16
Y	paragraphs [0093], [0135]; figures 9,16	1-9,17, 18
Y	----- US 2013/321788 A1 (OCKWELL DAVID CHRISTOPHER [NL] ET AL) 5 December 2013 (2013-12-05)	1-9,17, 18
A	paragraphs [0052] - [0056]; figures 4a,4b	10-16
A	----- US 2016/018744 A1 (LAFARRE RAYMOND WILHELMUS LOUIS [NL] ET AL) 21 January 2016 (2016-01-21) cited in the application paragraphs [0122], [0126] - [0140]; figures 18-20,24-27	1-18
	----- -/--	



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

6 May 2020

Date of mailing of the international search report

15/05/2020

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

Roesch, Guillaume

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2020/052945

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 2015/349669 A1 (BALDUS OLIVER [DE]) 3 December 2015 (2015-12-03) paragraphs [0040], [0041]; figures 1-4 -----	1-18

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2020/052945

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2013113568	A2	08-08-2013	
		CN 104081285 A	01-10-2014
		CN 104272190 A	07-01-2015
		CN 109254501 A	22-01-2019
		CN 109298602 A	01-02-2019
		CN 109375474 A	22-02-2019
		EP 2810127 A1	10-12-2014
		EP 2810128 A2	10-12-2014
		EP 3550364 A1	09-10-2019
		JP 5957540 B2	27-07-2016
		JP 6085616 B2	22-02-2017
		JP 6317785 B2	25-04-2018
		JP 6609341 B2	20-11-2019
		JP 2015507367 A	05-03-2015
		JP 2015508229 A	16-03-2015
		JP 2016187046 A	27-10-2016
		JP 2018117153 A	26-07-2018
		JP 2020024451 A	13-02-2020
		KR 20140114430 A	26-09-2014
		US 2014368804 A1	18-12-2014
		US 2015029485 A1	29-01-2015
		US 2016377994 A1	29-12-2016
		US 2017036272 A1	09-02-2017
		US 2017312826 A1	02-11-2017
		US 2019224755 A1	25-07-2019
		WO 2013113568 A2	08-08-2013
		WO 2013113569 A1	08-08-2013
US 2013321788	A1	05-12-2013	
		JP 5989677 B2	14-09-2016
		JP 2014507070 A	20-03-2014
		TW 201235798 A	01-09-2012
		US 2013321788 A1	05-12-2013
		WO 2012110144 A1	23-08-2012
US 2016018744	A1	21-01-2016	
		CN 105103052 A	25-11-2015
		EP 2979135 A2	03-02-2016
		JP 6145564 B2	14-06-2017
		JP 2016519332 A	30-06-2016
		KR 20150136527 A	07-12-2015
		US 2016018744 A1	21-01-2016
		WO 2014154428 A2	02-10-2014
US 2015349669	A1	03-12-2015	
		DE 102014008031 A1	03-12-2015
		US 2015349669 A1	03-12-2015