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(54) Title: RETICLE CAGE ACTUATOR WITH SHAPE MEMORY ALLOY AND MAGNETIC COUPLING MECHANISMS

(57) Abstract: Embodiments herein describe methods and safety devices used to provide support for an object. A safety device includes a driving side comprising a driving motor and a driven side. The driven side of the safety device includes a housing having a rotating shaft extending along a length of the housing and a safety latch. The driven side is coupled to the driving motor via a non-contact, magnetic coupling device at a first end of the rotating shaft, and the safety latch is coupled to a second end of the rotating shaft opposite from the first end of the rotating shaft. The driving motor is configured to cause rotation in a radial direction of the safety latch on the driving side via the non-contact, magnetic coupling device.

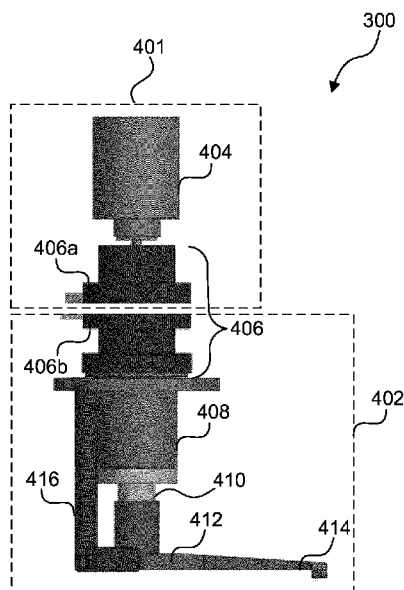


FIG. 4A

RETICLE CAGE ACTUATOR WITH SHAPE MEMORY ALLOY AND MAGNETIC COUPLING MECHANISMS

CROSS-REFERENCE TO RELATED APPLICATIONS

5 **[0001]** This application claims priority of U.S. Provisional Patent Application Number 62/845,022, which was filed on May 8, 2019, and which is incorporated herein in its entirety by reference.

FIELD

10 **[0002]** The present disclosure relates to safety mechanisms, such as a reticle cage actuator and magnetic coupling mechanism for the retention of a patterning device in a lithography system.

BACKGROUND

15 **[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 may 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
20 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
25 radiation beam in a given direction (the “scanning”-direction) while synchronously scanning the target portions parallel or anti-parallel to this scanning direction. It is also possible to transfer the pattern from the patterning device to the substrate by imprinting the pattern onto the substrate.

30 **[0004]** Lithography is widely recognized as one of the key steps in the manufacture of ICs and other devices and/or structures. However, as the dimensions of features made using lithography become smaller, lithography is becoming a more critical factor for enabling miniature IC or other devices and/or structures to be manufactured.

[0005] To project a pattern on a substrate a lithographic apparatus may use electromagnetic radiation. The wavelength of this radiation determines the minimum size of features which can be formed on the substrate. A lithographic apparatus, which uses extreme ultraviolet (EUV) radiation, having a wavelength within the range 4-20 nm, for example 6.7 nm or 13.5 nm, may be used to form smaller features on a substrate than a lithographic apparatus which uses, for example, radiation with a wavelength of 193 nm.

[0006] A lithographic apparatus using EUV radiation may require that the EUV radiation beam path, or at least substantial parts of it, must be kept in vacuum during a lithographic operation. In such vacuum regions of the lithographic apparatus, an electrostatic clamp may be used to clamp an object, such as a patterning device and/or a substrate to a structure of the lithographic apparatus, such as a patterning device table and/or a substrate table, respectively.

[0007] Conventional patterning devices, such as reticles, are very costly. As such, extreme care is taken when handling the reticles within the lithographic apparatus. Although the reticle is usually clamped to a chuck structure, it is desirable to include safety mechanisms in the event that the clamping fails. Otherwise, the reticle may fall and cause damage not only to the reticle itself, but also to other costly optics within the lithographic apparatus.

SUMMARY

[0008] Conventional safety designs may be used to ensure that a patterning device, such as a reticle, does not inadvertently fall away from a chuck (e.g., reticle stage). Such designs typically use electromagnets to open or close metallic arms to “catch” the reticle if it were to fall. These designs are not very efficient as they require a large motor to generate the force necessary to open the arms and also require constant power consumption to keep the arms in the open position. As a result of the power requirements, the safety designs also necessitate active cooling of the electromagnet to dissipate heat within the system. Furthermore, if power is cut off during operation, the arms of a safety latch powered by the electromagnet would automatically close and potentially damage a reticle, such as during a reticle exchange operation.

[0009] Accordingly, there is a need to provide new devices and methods for enhancing reticle safety mechanisms in a reliable and efficient manner. Embodiments herein describe systems, devices, and methods for an improved safety device that does not require electromagnets for reticle retention. The present disclosure provides a safety device that utilizes a permanent, non-

contact magnetic coupling for facilitating a rotational actuation mechanism in supporting a reticle in a lithography system. The magnetic coupling allows a shaft of the safety device to rotate without requiring physical contact between a driving carrier side and a chuck side, while minimizing power requirements through a bi-stable actuator mechanism. The present disclosure also includes devices and methods for a shape memory alloy (SMA) and compression spring-activated actuator for reticle safety. By applying a current or heat to a shape memory alloy of a safety device, a safety latch of the safety device may be actuated to an “open” or “closed” position in response to compression of a spring in the safety device that is activated by changes in the shape memory alloy.

[0010] In some embodiments, a safety device used to provide support for an object includes a driving side and a driven side. The driving side includes a driving motor. The driven side includes a housing having a rotating shaft extending along a length of the housing, and a safety latch, in which the driven side is coupled to the driving motor via a non-contact, magnetic coupling device at a first end of the rotating shaft. The safety latch is coupled to a second end of the rotating shaft opposite from the first end of the rotating shaft. The driving motor is configured to cause rotation in a radial direction of the safety latch on the driving side via the non-contact, magnetic coupling device.

[0011] In some embodiments, a lithographic apparatus includes an illumination system, a support structure, a projection system and one or more safety devices. The illumination system conditions a radiation beam. The support structure is constructed to support a patterning device that is capable of imparting the radiation beam with a pattern in its cross-section to form a patterned radiation beam. The projection system is configured to project the patterned radiation beam onto a target portion of a substrate. The one or more safety devices are coupled to the support structure and each includes a driving side and a driven side. The driving side of the one or more safety devices includes a driving motor. The driven side of the one or more safety devices includes a housing having a rotating shaft extending along a length of the housing, and a safety latch, in which the driven side is coupled to the driving motor via a non-contact, magnetic coupling device at a first end of the rotating shaft. The safety latch is coupled to a second end of the rotating shaft opposite from the first end of the rotating shaft. The driving motor is configured to cause rotation in a radial direction of the safety latch on the driving side via the non-contact, magnetic coupling device.

[0012] In some embodiments, a method includes using a safety device used to support a patterning device, the safety device having an actuator with at least one shape memory alloy, a safety latch, and at least one spring coupled to the safety latch. The safety latch includes a foot portion at a distal end of the safety latch, in which the foot portions is configured to act as a contact point for the patterning device. The method also includes applying a current to the at least one shape memory alloy of the safety device to activate the at least one shape memory alloy and actuating the safety latch from a first position to a second position below the patterning device in response to activation of the at least one shape memory alloy.

[0013] Further features and advantages, as well as the structure and operation, of various embodiments of the invention are described in detail below with reference to the accompanying drawings. It is noted that the invention is not limited to the specific embodiments described herein. Such embodiments are presented herein for illustrative purposes only. Additional embodiments will be apparent to persons skilled in the relevant art(s) based on the teachings contained herein.

BRIEF DESCRIPTION OF THE DRAWINGS/FIGURES

[0014] The accompanying drawings, which are incorporated herein and form part of the specification, illustrate the present invention and, together with the description, further serve to explain the principles of the invention and to enable a person skilled in the relevant art(s) to make and use the invention.

[0015] FIG. 1 is a schematic illustration of a lithographic apparatus, according to an embodiment of the present disclosure.

[0016] FIG. 2 is a perspective schematic illustration of a reticle stage, according to an embodiment of the present disclosure.

[0017] FIG. 3 is a top plan view of the reticle stage of Figure 2.

[0018] FIGs. 4A and 4B are schematic illustrations of a safety device, according to embodiments of the present disclosure.

[0019] FIG. 5 is a schematic illustration showing an isometric view of the safety device of FIGs. 4A and 4B, according to embodiments of the present disclosure.

[0020] FIGs. 6A, 6B, and 6C are schematic illustrations of example magnetic coupling configurations for a safety device, according to embodiments of the present disclosure.

[0021] FIG. 7 is a schematic illustration of rotating the safety latch, according to embodiments of the present disclosure.

[0022] FIGs. 8A and 8B are schematic illustrations showing front views of shape memory alloy (SMA) actuator mechanisms, according to embodiments of the present disclosure.

5 **[0023]** FIGs. 9A and 9B are schematic illustrations showing top views of shape memory alloy (SMA) actuator mechanisms, according to embodiments of the present disclosure.

[0024] FIGs. 10A-10D are schematic illustrations of a shape memory alloy actuator and safety device for reticle safety, according to embodiments of the present disclosure.

10 **[0025]** FIG. 11 is a schematic illustration of a flowchart for operating a safety device for supporting a patterning device, according to embodiments of the present disclosure.

[0026] The features and advantages of the present invention will become more apparent from the detailed description set forth below when taken in conjunction with the drawings, in which like reference characters identify corresponding elements throughout. In the drawings, like reference numbers generally indicate identical, functionally similar, and/or structurally similar elements. Unless otherwise indicated, the drawings provided throughout the disclosure should not
15 be interpreted as to-scale drawings.

DETAILED DESCRIPTION

[0027] This specification discloses one or more embodiments that incorporate the features
20 of this invention. The disclosed embodiment(s) merely exemplify the invention. The scope of the invention is not limited to the disclosed embodiment(s). The invention is defined by the claims appended hereto.

[0028] The embodiment(s) described, and references in the specification to “one
25 embodiment,” “an embodiment,” “an example embodiment,” etc., indicate that the embodiment(s) described may include a particular feature, structure, or characteristic, but every embodiment may not necessarily include the particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is understood that it is within the knowledge of one skilled in the art to affect such feature, structure, or characteristic in
30 connection with other embodiments whether or not explicitly described.

[0029] Spatially relative terms, such as “beneath,” “below,” “lower,” “above,” “on,” “upper” and the like, may be used herein for ease of description to describe one element or feature’s relationship to another element(s) or feature(s) as illustrated in the figures. The spatially relative terms are intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. The apparatus may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein may likewise be interpreted accordingly.

[0030] The term “about” as used herein indicates the value of a given quantity that can vary based on a particular technology. Based on the particular technology, the term “about” can indicate a value of a given quantity that varies within, for example, 10–30% of the value (e.g., $\pm 10\%$, $\pm 20\%$, or $\pm 30\%$ of the value).

[0031] Embodiments of the disclosure may be implemented in hardware, firmware, software, or any combination thereof. Embodiments of the disclosure 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 machine-readable medium may include read only memory (ROM); random access memory (RAM); magnetic disk 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, and/or instructions may be described herein as performing certain actions. However, it should be appreciated that such descriptions are merely for convenience and that 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.

[0032] Before describing such embodiments in more detail, however, it is instructive to present an example environment in which embodiments of the present disclosure may be implemented.

[0033] *Example Lithographic System*

[0034] FIG. 1 shows a lithographic system comprising a radiation source SO and a lithographic apparatus LA. The radiation source SO is configured to generate an EUV radiation

beam B and to supply the EUV radiation beam B to the lithographic apparatus LA. The lithographic apparatus LA comprises an illumination system IL, a support structure (for example, mask table) MT configured to support a patterning device MA (e.g., a mask), a projection system PS, and a substrate table WT configured to support a substrate W. In general, movement of the support structure MT can be realized with the aid of a long-stroke module (coarse positioning) and a short-stroke module (fine positioning), as further described below.

[0035] The illumination system IL is configured to condition the EUV radiation beam B before the EUV radiation beam B is incident upon the patterning device MA. Thereto, the illumination system IL may include a faceted field mirror device 10 and a faceted pupil mirror device 11. The faceted field mirror device 10 and faceted pupil mirror device 11 together provide the EUV radiation beam B with a desired cross-sectional shape and a desired intensity distribution. The illumination system IL may include other mirrors or devices in addition to, or instead of, the faceted field mirror device 10 and faceted pupil mirror device 11.

[0036] After being thus conditioned, the EUV radiation beam B interacts with the patterning device MA. As a result of this interaction, a patterned EUV radiation beam B' is generated. The projection system PS is configured to project the patterned EUV radiation beam B' onto the substrate W. For that purpose, the projection system PS may comprise a plurality of mirrors 13, 14 which are configured to project the patterned EUV radiation beam B' onto the substrate W held by the substrate table WT. The projection system PS may apply a reduction factor to the patterned EUV radiation beam B', thus forming an image with features that are smaller than corresponding features on the patterning device MA. For example, a reduction factor of 4 or 8 may be applied. Although the projection system PS is illustrated as having only two mirrors 13, 14 in FIG. 1, the projection system PS may include a different number of mirrors (e.g. six or eight mirrors).

[0037] The substrate W may include previously formed patterns. Where this is the case, the lithographic apparatus LA aligns the image, formed by the patterned EUV radiation beam B', with a pattern previously formed on the substrate W.

[0038] A relative vacuum, i.e. a small amount of gas (e.g. hydrogen) at a pressure well below atmospheric pressure, may be provided in the radiation source SO, in the illumination system IL, and/or in the projection system PS.

[0039] The radiation source SO may be a laser produced plasma (LPP) source, a discharge produced plasma (DPP) source, a free electron laser (FEL), or any other radiation source that is capable of generating EUV radiation.

[0040] *Example Reticle Stage and Safety Device Systems*

5 [0041] FIGs. 2 and 3 show schematic illustrations of an exemplary reticle stage 200, according to some embodiments of this disclosure. Reticle stage 200 can include top stage surface 202, bottom stage surface 204, side stage surfaces 206, reticle 208, and safety device 300. In some embodiments, reticle stage 200 with reticle 208 can be implemented in lithographic apparatus LA. For example, reticle stage 200 can represent support structure MT and reticle 208 can represent
10 patterning device MA in lithographic apparatus LA. In some embodiments, reticle 208 and a plurality of safety devices 300 can be disposed on top stage surface 202. For example, as shown in FIG. 2, reticle 208 can be disposed at a center of top stage surface 202 with safety devices 300 disposed adjacent to each corner of reticle 208.

[0042] In some lithographic apparatuses, for example, lithographic apparatus LA, a reticle
15 stage or chuck 200 can be used to hold and position a reticle 208 for scanning or patterning operations. Reticle stage 200 requires powerful drives, large balance masses, and heavy frames to support it. Reticle stage 200 has a large inertia and can weigh over 500 kg to propel and position reticle 208 weighing about 0.5 kg. To accomplish reciprocating motions of reticle 208, which are typically found in lithographic scanning or patterning operations, accelerating and decelerating
20 forces can be provided by linear motors that drive reticle stage 200.

[0043] During a catastrophic failure of reticle stage 200, for example, by major power loss or serious system failure, the accelerating and decelerating forces of reticle stage 200 can be transferred to reticle 208 and result in a reticle crash. Reticle 208 can crash into other components of reticle stage 200, causing damage to reticle 208 and/or other nearby components. Reticle 208
25 can crash at a high force (i.e., high acceleration) depending on the pre-crash motion and momentum of reticle stage 200. Softer reticle flexure can lead to metal breaks (e.g., pattern damage), while harder reticle flexure can lead to glass breaks (e.g., cracks in reticle). Current methods use some form of a safety mechanism to reduce or decrease the force of a reticle during a crash. However, due to the high impact stress (force) of the reticle in worst case crashes, damage can still occur to
30 the reticle and/or current safety mechanisms.

[0044] One possible solution is to position a safety mechanism, for example, safety devices 300 around reticle 208 to act as a shock absorber to reduce an impact force of reticle 208 during a crash. For example, a bumper apparatus 201 with shock absorbers can be used around reticle 208 to absorb possible forces or shocks occurring from a crash such that damage to reticle 208 and safety devices 300 can be reduced or eliminated completely. According to an embodiment, safety devices 300 can also each include a safety latch (not shown) that is rotated in place beneath reticle 208 such that the safety latch prevents reticle 208 from falling away from reticle stage 200. Reticle 208 may be restrained by four safety devices 300, for example, arranged adjacent to the corners of reticle 208. In an embodiment, safety devices 300 may act like a “cage” used to contain an object from shifting or falling. When safety devices 300 are used to provide emergency support for a reticle, they may be collectively called a reticle cage, but safety devices 300 can also be used to support other types of patterning devices, or any other type of clamped object.

[0045] In some embodiments, as shown in FIGS. 2 and 3, reticle stage 200 can include first encoder 212 and second encoder 214 for positioning operations. For example, first and second encoders 212, 214 can be interferometers. First encoder 212 can be attached along a first direction, for example, a transverse direction (i.e., X-direction) of reticle stage 200 and second encoder 214 can be attached along a second direction, for example, a longitudinal direction (i.e., Y-direction) of reticle stage 200. In some embodiments, as shown in FIGS. 2 and 3, first encoder 212 can be orthogonal to second encoder 214.

[0046] Safety devices 300 can be configured to secure and reduce damage to reticle 208 during a crash. Safety devices 300 can be configured to uniformly distribute an impact force of reticle 208 during a crash. In some embodiments, a plurality of safety devices 300 can be disposed in top stage surface 202 and arranged around a perimeter of reticle 208. For example, multiple safety devices 300 can be disposed adjacent each corner of reticle 208 to uniformly distribute an impact force of reticle 208 over a plurality of impact locations.

[0047] In some embodiments, safety devices 300 can be utilized for holding reticle 208 in place (e.g., with a safety latch), such as during a reticle exchange operation or manual recovery of reticle 208. Safety devices 300 are also useful for preventing reticle 208 from displacement in the Z direction if the reticle disengages from an electrostatic clamp that holds the reticle during a scan.

[0048] *Example Designs of Safety Device with Magnetic Coupling*

[0049] FIGs. 4A and 4B illustrate example views of one safety device 300, according to embodiments of the present disclosure. In particular, FIG. 4A illustrates a side view of safety device 300, whereas FIG. 4B illustrates a cross-sectional view of safety device 300. As discussed above in FIGs. 2-3, one or more of safety device 300 may be disposed around reticle 208 and coupled to a chuck (e.g., reticle stage 200.)

[0050] Safety device 300 includes a driving side 401 (e.g., on a carrier) and a driven side 402 (e.g., on a chuck). In particular, driving side 401 includes the mover component of the safety device 300, whereas driven side 402 includes the follower component which reacts to the motion of the driving side 401. Driving side 401 includes a driving motor 404, a driving component 406a, and sensor 418.

[0051] In some embodiments, sensor 418 comprises a position sensor configured to sense proximity or position of an object or a target (e.g., target 420). For example, sensor 418 may be a capacitive sensor, inductive sensor, optically reflective sensor, break-beam sensor, or the like. In some embodiments, sensor 418 may be located on the driving side 401 (e.g., carrier), whereas the object that the sensor 418 senses may be located on the driven side 402 (e.g., chuck). In other embodiments, both sensor 418 and the object that the sensor 418 senses may be located on the driven side 402 (e.g., chuck). In some cases, if the sensor 418 and the object are located on different sides of the safety device 300 (e.g., sensor 418 on driving side 401 and object on driven side 402, or vice versa), the movements of the driven side 402 and driving side 401 may affect the sensor data. By having both the sensor 418 and the object located on the driven side 402, the driven side 402 and driving side 401 may move relative to each other without affecting the sensor data.

[0052] Driving motor 404 is the component that moves and controls the movement of safety device 300. In some embodiments, driving motor 404 may be a rotary motor, an actuator, and/or a direct drive, bi-stable actuator. In particular, driving motor 404 drives or actuates the driving component 406a, which is a part of a magnetic coupling device 406. Alternatively, a rotary solenoid may be used instead of a motor, or another electrical rotary motor with a braking mechanism. The bi-stable nature of driving motor 404 means that motion of the motor only occurs while under power. No power is consumed by driving motor 404 while it is fixed in a given position. Driving motor 404 may be a piezoelectric motor or DC motor.

[0053] Magnetic coupling device 406 provides a non-contact permanent magnetic coupling for safety device 300. Magnetic coupling device 406 includes two components: driving

component 406a and driven component 406b. The two components 406a and 406b have permanent magnets facing each other, but not in contact with each other. For example, driving component 406a and driven component 406b may be physically separated by a space of about 1-4 mm. The attractive forces between the permanent magnets of driving component 406a and driven component 406b allows the driving side 401 to drive or move the driven side 402 of the safety device in a rotary manner.

[0054] Driven side 402 includes driven component 406b, housing 408, shaft 410, safety bumper 416, safety latch 412, foot region 414, safety bumper 416, and target 420. Through the magnetic coupling 406, driven component 406b reacts to the motion of driving component 406a, resulting in a non-contact transmission of mechanical energy to the driven side 402. Housing 408 of driven side 402 may have a longest length along the Z-axis, and may be provided to protect moving components disposed inside. Housing 408 may be an injection molded material, such as a polymer material, or housing 408 may be machined metal. In some embodiments, housing 408 may have a length along the Z-direction of about 20-70 millimeters.

[0055] Housing 408 includes shaft 410, which is attached to driving motor 404 via the magnetic coupling device 406. In particular, shaft 410 may be disposed within housing 408, while the magnetic coupling device 406 may be coupled to one end of shaft 410 outside of housing 408. Shaft 410 may extend along the length of housing 408.

[0056] Safety bumper 416 may also be included as part of the motor design and disposed within driven side 402 of the safety device. Any type of bushing or bearing design may be used in the safety bumper design. According to some embodiments, one or more safety bumpers 416 may be included in safety device 300 to act as a stopping mechanism in the X and Y directions for the reticle, once the reticle loses clamping force to the driven side 402 (e.g., chuck). Safety bumpers 416 are described in more detail in U.S. App. No. 62/768,161, which is incorporated by reference herein in its entirety.

[0057] Safety device 300 also includes a safety latch 412 that is coupled to an opposite end of shaft 410 from the end coupled to the magnetic coupling device 406. Safety latch 412 rotates along with rotating shaft 410. In some embodiments, safety latch 412 can rotate a full 360 degrees beneath housing 408 about an axis parallel to the Z-direction. Safety latch 412 extends outward radially from shaft 410 and may have a length of less than 60 mm. For example, safety latch 412 may have a length greater than 10 mm and less than 60 mm. The exact illustrated design of safety

latch 412 is only one example and is not intended to be limiting. Safety latch 412 may include two or more separate beams as illustrated in FIGs. 4A, 4B, or 5, or it may be one solid piece.

[0058] In some embodiments, a foot region 414 may be disposed at a distal end of safety latch 412. Foot region 414 may be referred to as safety foot/feet or reticle foot/feet. Foot region 414 may be substantially flat and designed to contact a portion of a patterning device (e.g., reticle). According to some embodiments, foot region 414 is the only portion of safety latch 412 that would have any contact with a patterning device if the device were to fall in the Z-direction from its clamped position.

[0059] The cross-section view of FIG. 4B further illustrates additional components of safety device 300, including a particle seal 422, upper end particle seal 424, bearings 426, and lower end particle seal 428. Bearings 426 include ceramic components that bear friction between the rotating parts in the housing 408. Particle seals 422, 424, and 428 may be designed such that particles generated from the moving parts during rotation of safety latch 412 remain trapped within housing 408 and are not expelled out into the space around safety device 300. In some embodiments, upper end particle seal 424, bearings 426, and lower end particle seal 428 may be disposed within the housing 408 of the safety device.

[0060] FIG. 5 illustrates a schematic diagram of an isometric view of safety device 300 of FIGs. 4A and 4B, according to embodiments of the present disclosure. Safety device 300 includes driving motor 404, magnetic coupling device 406, housing 408, shaft 410, safety latch 412, and foot region 414, and safety bumper 416.

[0061] As shown in FIG. 5, foot region 414 may be bent away from a remainder of safety latch 412 at an angle, such as about a 90 degree angle. According to some embodiments, a sloped member (not shown) may connect safety latch 412 to foot region 414, such that foot region 414 is disposed at a lower, parallel plane than safety latch 412.

[0062] In some embodiments, safety device 300 may be a rigid material, for example, a metal or a ceramic. In some embodiments, housing 408 of safety device 300 may be cylindrical and extend through a portion of reticle stage 200 for rigid alignment with a corner of a reticle. In some embodiments, safety latch 412 may be configured to secure (e.g., catch) and reduce damage to a reticle during a crash. For example, foot region 414 of safety latch 412 may extend over a top surface of a reticle and be configured to prevent movement of the reticle in a direction perpendicular to the surface of a top stage surface 202 (e.g., Z-direction).

[0063] FIGs. 6A, 6B, and 6C illustrate schematic diagrams of example magnetic coupling configurations for a safety device, according to embodiments of the present disclosure. In particular, FIG. 6A illustrates a face to face magnetic coupling configuration 600, FIG. 6B illustrates a coaxial magnetic coupling configuration 610, and FIG. 6C illustrates an example of a magnetic coupling surface 620.

[0064] The face to face magnetic coupling configuration 600 of FIG. 6A is a face to face magnetic coupling mechanism in which the surfaces of driving component 406a and driven component 406b are placed adjacent to each other with a material in between. The surfaces of driving component 406a and driven component 406b are lined with a plurality of permanent magnets that are attracted to each other, resulting in the magnetic coupling device 406. In some embodiments, the surfaces of driving component 406a and driven component 406b may be separated by a material with a predetermined thickness in between the two components (e.g., a distance of about 1.5 mm – 6 mm may separate the driving component 406a and driven component 406b).

[0065] The coaxial magnetic coupling configuration 610 of FIG. 6B is a coaxial magnetic coupling mechanism in which the cylindrical ends of the driving component 406a and driven component 406b are concentrically coupled to each other. The cylindrical ends of the driving component 406a and driven component 406b may be separated by a material (e.g., an insulator) in order to provide a non-contact magnetic coupling mechanism in the safety device. In some embodiments, an outer cylindrical end of driving component 406a may be coupled concentrically with an inner cylindrical end of driven component 406b. For example, the inner surfaces of the outer cylindrical end of driving component 406a may be lined with permanent magnets that are attracted to permanent magnets with opposite poles that are lined on the outer surfaces of the inner cylindrical end of driven component 406b.

[0066] In other embodiments, an outer cylindrical end of driven component 406b may be coupled concentrically with an inner cylindrical end of driving component 406a. For example, the inner surfaces of the outer cylindrical end of driven component 406b may be lined with permanent magnets that are attracted to permanent magnets with opposite poles that are lined on the outer surfaces of the inner cylindrical end of driving component 406a.

[0067] FIG. 6C further illustrates an example of a magnetic coupling surface 620. The magnetic coupling surface 620 may represent the surface of driving component 406a and/or the

surface of driven component 406b in a face to face coupling mechanism (e.g., face to face magnetic coupling configuration 600). The coupling surface 620 may include a plurality of magnets 625 arranged on the surface of driving component 406a and/or driven component 406b in a circular manner. In some embodiments, the spacing between the magnets 625 and the number of magnets 625 may be selected based on the resolution of the motion of the driving motor 404 and the coupling strength of the driving component 406a and driven component 406b.

[0068] While FIGs. 6A-6C only show two magnetic coupling configurations, it should be understood that the magnetic coupling device 406 may utilize other embodiments of magnetic coupling mechanisms or configurations for coupling the driving component 406a with the driven component 406b. By utilizing various magnetic coupling mechanisms (e.g., a face to face coupling mechanism, a coaxial coupling mechanism, or the like), the driven side of the safety device may be moved based on its connection to the driving side with the driving motor.

[0069] Additionally, the non-contact magnetic coupling device 406 may be advantageous by providing a bi-stable actuation mechanism in which vibrations on the driving side 401 (where the driving motor 404 is located) are physically isolated from the driven side 402, such that the transfer of vibrations or disturbances to the chuck is greatly reduced. Furthermore, the separation between the driving side 401 and the driven side 402 in the safety device provides a barrier or particle trap between the two sides which helps to keep out particles from the driving side 401. In some embodiments, since the coupling is connected magnetically, the present disclosure allows for some misalignment (e.g., axial and angular) between the couplings (e.g., between driving component 406a and driven component 406b), while maintaining the bi-stable actuation mechanism. In other words, when the driving side 401 is not actuated, the driven side 402 remains in position.

[0070] FIG. 7 illustrates a top-down view of patterning device 208 and safety device 300 adjacent to one corner of patterning device 208, according to embodiments of the present disclosure. It should be noted that FIG. 7 is not drawn to scale and that certain features have been made larger for clarity. Furthermore, the location of safety device 300 with respect to patterning device 208 is not intended to be limiting – safety device 300 may be located anywhere around the perimeter of patterning device 208.

[0071] As shown in FIG. 7, safety latch 412 of safety device 300 rotates between a first position shown on the left and a second position shown on the right. In the first position, foot

region 414 is aligned beneath patterning device 208, such that patterning device 208 contacts foot region 414 if patterning device 208 detaches from the chuck (not shown in FIG. 7) and fell in the Z-direction. In the second position, safety latch 412 has rotated away from patterning device 208, such that no part of safety latch 412 is below patterning device 208. According to an embodiment, safety latch 412 would be rotated into the first position while patterning device 208 is clamped to the chuck. According to an embodiment, safety latch 412 would be rotated into the second position during either loading or removal of patterning device 208 from the chuck. An angle of rotation θ for safety latch 412 between the first position and the second position may be between 5 degrees and 20 degrees. Other rotation angles are possible as well based on the length of safety latch 412.

[0072] In some embodiments, an advantage of using a safety device with a bi-stable motor (e.g., driving motor 404) and a magnetic coupling device to rotate safety latch 412 is that the motor only consumes power during the rotation and not while safety latch 412 is stationary in either the first position or the second position. For example, the motor is powered solely when rotating the safety latch 412 from the first position to the second position, and vice versa, for a short duration of time (e.g., 0.5 second to 3 seconds). Thus, the motor does not necessitate being turned on for long durations of time, and ultimately does not require active cooling.

[0073] In some embodiments, a safety device 300 with a magnetic coupling might not rely on rotary or compression springs to provide the force for maintaining safety latch 412 in the first position. Furthermore, safety device 300 with the driving motor and magnetic coupling device may have a lower mass compared to previous safety designs (e.g., safety devices using electromagnets).

[0074] *Example Shape Memory Alloy (SMA) Mechanisms for Safety Devices*

[0075] FIGs. 8A and 8B illustrate example diagrams of shape memory alloy (SMA) actuator mechanisms for safety devices (e.g., safety device 300), according to embodiments of the present disclosure. In particular, FIG. 8A illustrates a front view of an actuator mechanism 800 in a first position (e.g., a closed position), whereas FIG. 8B illustrates a front view of an actuator mechanism 810 in a second position (e.g., an open position).

[0076] Actuator mechanisms 800 and 810 include a shape memory alloy 802, a pin joint 804, a spring 806, a safety latch 808, and reticle feet 809. The motion of actuator mechanisms 800 and 810 in a safety device occurs by displacement of the safety latch 808 in the Z direction (e.g., a lever or see-saw mechanism). While only one shape memory alloy 802, pin joint 804, and spring 806 are shown in FIGs. 8A and 8B, the actuator mechanisms 800 and 810 may utilize any number

of shape memory alloys 802, pin joints 804, and/or springs 806 in a safety device in order to increase actuation forces in the safety device.

[0077] In FIG. 8A, the actuator mechanism 800 is shown in a non-actuated, closed position, such as during a reticle scan when the reticle (e.g., 208) is clamped to a surface of the chuck. The spring 806 may hold the actuator in the closed position until it is actuated. For example, the spring 806 may be a tension spring. In some embodiments, the shape memory alloy 802 and the spring 806 may be preselected based on the actuation forces required to actuate the device and the holding forces required to hold the actuator in the closed position. In particular, a see-saw mechanism may be used to convert the linear motion of the shape memory alloy 802 to a swing in the safety latch 808 in the Z direction.

[0078] In order to rotate the safety latch 808 to an open position as shown by actuator mechanism 810 in FIG. 8B, a current 811 may be applied to the shape memory alloy 802 to activate the shape memory alloy 802 (e.g., by heating) and cause the safety latch 808 to move (e.g., rotate). Upon releasing or removing the current 811, the spring 806 may compress and cause the safety latch 808 to return from the open position in FIG. 8B to the closed position in FIG. 8A. In some embodiments, the shape memory alloy 802 may be cooled to facilitate the return of the shape memory alloy 802 to its original shape (e.g., closed position or open position).

[0079] In some embodiments, the safety latch 808 may have a length of about 15 mm and may be rotated from the closed position to the open position by a predetermined angle of rotation between about 5 degrees and about 20 degrees in response to activation of the shape memory alloy 802. In some embodiments, the safety latch 808 may be rotated by about 5 mm from the closed position to the open position, or vice versa. The reticle feet 809 may be disposed at a distal end of the safety latch 808 at an angle (e.g., 90 degrees) from a remainder of the safety latch 808.

[0080] FIGs. 9A and 9B illustrate additional example diagrams of shape memory alloy (SMA) actuator mechanisms for safety devices (e.g., safety device 300), according to embodiments of the present disclosure. In particular, FIG. 9A illustrates a top view of an actuator mechanism 900 in a first position (e.g., a closed position), whereas FIG. 9B illustrates a top view of an actuator mechanism 910 in a second position (e.g., an open position).

[0081] Actuator mechanisms 900 and 910 utilize a rotary configuration, in which shape memory alloys 902 and springs 906 are integrated in a driving motor 404 and coupled to a safety latch 908 with reticle feet 909. While three shape memory alloys 902 and springs 906 are shown

in FIGs. 9A and 9B, the actuator mechanisms 900 and 910 may utilize any number of shape memory alloys 902 and/or springs 906 in a safety device in order to decrease or increase actuation forces in the safety device. In some embodiments, springs 906 may be expansion springs and/or compression springs, and the safety latch 908 in actuator mechanisms 900 and 910 may be displaced in the X and Y directions as shown by the top views of FIGs. 9A and 9B.

[0082] For example, springs 906 may be compression springs arranged in parallel with the shape memory alloys 902 in actuator mechanisms 900 and 910. When current is applied to the shape memory alloys 902, the shape memory alloys 902 may heat up and expand, causing rotation of the safety latch 908 from a first position to a second position. Once the current is switched off, the springs 906 may compress and facilitate in the contraction of the shape memory alloys 902 to its previous shape/configuration, resulting in rotation of the safety latch 908 from the second position back to the first position.

[0083] In another example, springs 906 may be expansion springs arranged in parallel with the shape memory alloys 902 in actuator mechanisms 900 and 910. The shape memory alloys 902 may resist the expansion of the springs 906 until current has passed through the shape memory alloys 902. In some cases, once current has been applied to the shape memory alloys 902, the shape memory alloys 902 expand, and the springs 906 facilitate the expansion of the shape memory alloys 902, causing rotation of the safety latch 908 from a first position to a second position. Once the current is switched off, the shape memory alloys 902 cool and contract to its original position, while also contracting the springs 906 back into their original position. This contraction results in rotation of the safety latch 908 from the second position back to the first position

[0084] In some embodiments, actuator mechanisms 800, 810, 900, and/or 910 may be combined with the magnetic coupling device 406 shown in FIGs. 4A, 4B, and 5 in order to provide an enhanced safety device. FIGs. 10A-10D show examples of a shape memory alloy actuator and safety device for reticle safety, according to embodiments of the present disclosure. In particular, FIG. 10A illustrates a schematic illustration of a top view of safety device 1000, FIG. 10B illustrates a side view of safety device 1010, and FIG. 10C illustrates an isometric view of safety device 1020. FIG. 10D illustrates an isometric view of the shape memory alloy actuator and safety device in a chuck 1030.

[0085] The safety devices shown in FIGs. 10A-10C include shape memory alloys 1002 arranged in parallel with springs 1006, and coupled to safety latch 1008 with reticle feet 1009. In

some embodiments, the shape memory alloys 1002 and springs 1006 may be packaged or integrated into a rotary driving motor 1004, which may be utilized to drive the safety latch for displacement in the X and Y directions.

[0086] *Example Method of Operation*

5 **[0087]** FIG. 11 is a flowchart of an exemplary method 1100 for operating a safety device for supporting a patterning device, according to embodiments of the present disclosure. Method 1100 may describe the operation of safety device 300 and its corresponding safety latch 412 as discussed above with reference to FIGs. 2-10. It should be understood that the operations shown in method 1100 are not exhaustive and that other operations can be performed as well before, after,
10 or between any of the illustrated operations. In various embodiments of the present disclosure, the operations of method 1100 can be performed in a different order and/or vary.

[0088] In operation 1102, a safety device is used to support a patterning device. The safety device may include an actuator with at least one shape memory alloy, a safety latch, and at least one spring coupled to the safety latch. The safety latch includes a foot portion at a distal end of the
15 safety latch, in which the foot portion is configured to act as a contact point for the patterning device. In some embodiments, the safety device may be used in a rotary configuration. In other embodiments, the safety device may be used in a see-saw configuration.

[0089] In operation 1104, a current is applied to the at least one shape memory alloy of the safety device to activate the at least one shape memory alloy. In some embodiments, the activation
20 of the at least one shape memory alloy may include expansion of the at least one shape memory alloy, along with expansion of the at least one spring in the safety device. In other embodiments, the activation of the at least one shape memory alloy may include compression of the at least one shape memory alloy, along with compression of the at least one spring in the safety device.

[0090] In operation 1106, the safety latch of the safety device is actuated from a first
25 position to a second position below the patterning device in response to activation of the at least one shape memory alloy. In some embodiments, expansion of the shape memory alloy may result in rotation of the safety latch from an “open” position to a “closed” position, or vice versa. The safety latch includes a foot portion at a distal end of the safety latch, in which the foot portion is configured to act as a contact point for the reticle. It should be understood that any position of the
30 safety latch may be considered an “open” position so long as the safety latch is not in the way of loading a reticle to the reticle chuck

[0091] In operation 1108, the current is removed from the at least one shape memory alloy of the safety device. In some embodiments, the current may be removed by cooling the shape memory alloy 802 or by turning off the current source to the at least one shape memory alloy.

[0092] In operation 1110, the safety latch of the safety device is actuated from the second position to the first position in response to the removal of current from the at least one shape memory alloy. In some cases, the shape memory alloy may contract to its original position, which results in the rotation of the safety latch from the “closed” position to the “open” position, or vice versa.

[0093] The embodiments may further be described using the following clauses:

1. A safety device used to provide support for an object, comprising:
 - a driving side comprising a driving motor; and
 - a driven side comprising:
 - a housing comprising a rotating shaft extending along a length of the housing; and
 - a safety latch,
 - wherein the driven side is coupled to the driving motor via a non-contact, magnetic coupling device at a first end of the rotating shaft,
 - wherein the safety latch is coupled to a second end of the rotating shaft opposite from the first end of the rotating shaft, and
 - wherein the driving motor is configured to cause rotation in a radial direction of the safety latch on the driving side via the non-contact, magnetic coupling device.
2. The safety device of clause 1, wherein:
 - the non-contact, magnetic coupling device comprises two components; and
 - a plurality of permanent magnets are arranged on the adjacent surfaces of the two components and provide attractive forces between the two components of the magnetic coupling device.
3. The safety device of clause 1, wherein the non-contact, magnetic coupling device comprises a face to face coupling mechanism.
4. The safety device of clause 1, wherein the non-contact, magnetic coupling device comprises a co-axial coupling mechanism.

5. The safety device of clause 1, wherein the safety latch is configured to rotate between a first position and a second position, the first position and the second position being separated by angle between about 5 degrees and about 20 degrees.

6. The safety device of clause 1, wherein the driving motor comprises a piezoelectric motor or a bi-stable DC motor.

7. The safety device of clause 1, wherein the safety latch comprises a foot portion at a distal end of the safety latch away from the rotating shaft, the foot portion being configured to act as a contact point for the object.

8. A lithographic apparatus, comprising:

an illumination system configured to condition a radiation beam;

a support structure constructed to support a patterning device, the patterning device being capable of imparting the radiation beam with a pattern in its cross-section to form a patterned radiation beam;

a projection system configured to project the patterned radiation beam onto a target portion of a substrate; and

one or more safety devices coupled to the support structure, each of the one or more safety devices comprising:

a driving side comprising a driving motor; and

a driven side comprising:

a housing comprising a rotating shaft extending along a length of the housing; and

a safety latch,

wherein the driven side is coupled to the driving motor via a non-contact, magnetic coupling device at a first end of the rotating shaft,

wherein the safety latch is coupled to a second end of the rotating shaft opposite from the first end of the rotating shaft, and

wherein the driving motor is configured to cause rotation in a radial direction of the safety latch on the driving side via the non-contact, magnetic coupling device.

9. The lithographic apparatus of clause 8, wherein:

non-contact, magnetic coupling device comprises two components; and

a plurality of permanent magnets are arranged on the adjacent surfaces of the two components and provide attractive forces between the two components of the magnetic coupling device.

10. The lithographic apparatus of clause 8, wherein the non-contact, magnetic coupling device comprises a face to face coupling mechanism.

11. The lithographic apparatus of clause 8, wherein the non-contact, magnetic coupling device comprises a co-axial coupling mechanism.

12. The lithographic apparatus of clause 8, wherein the safety latch is configured to rotate between a first position and a second position, the first position and the second position being separated by angle between about 5 degrees and about 20 degrees.

13. The lithographic apparatus of clause 8, wherein the driving motor comprises a piezoelectric motor or a bi-stable DC motor.

14. The lithographic apparatus of clause 8, wherein the safety latch comprises a foot portion at a distal end of the safety latch away from the rotating shaft, the foot portion being configured to act as a contact point for the patterning device.

15. A method comprising:

using a safety device to support a patterning device, the safety device comprising an actuator with at least one shape memory alloy, a safety latch, and at least one spring coupled to the safety latch, the safety latch comprising a foot portion at a distal end of the safety latch, the foot portion being configured to act as a contact point for the patterning device;

applying a current to the at least one shape memory alloy of the safety device to activate the at least one shape memory alloy; and

actuating the safety latch from a first position to a second position below the patterning device in response to activation of the at least one shape memory alloy.

16. The method of clause 15, wherein the using comprises using the at least one shape memory alloy and the at least one spring in the actuator coupled to the safety latch in a rotary configuration.

17. The method of clause 15, wherein the using comprises using the at least one shape memory alloy and the at least one spring in the actuator coupled to the safety latch in a seesaw configuration.

18. The method of clause 15, further comprising:

removing the current from the at least one shape memory alloy of the safety device to actuate the safety latch from the second position to the first position.

19. The method of clause 15, further comprising:

expanding the at least one spring in response to applying the current to the at least one shape memory alloy.

20. The method of clause 15, further comprising:

5 compressing the at least one spring in response to applying the current to the at least one shape memory alloy.

[0094] *Final Remarks*

[0095] Although specific reference may be made in this text to a “reticle,” it should be understood that this is just one example of a patterning device and that the embodiments described
10 herein may be applicable to any type of patterning device. Additionally, the embodiments described herein may be used to provide safety support for any object to ensure a clamping failure does not cause the object to fall and damage either itself or other equipment.

[0096] Although specific reference may be made in this text to the use of lithographic apparatus in the manufacture of ICs, it should be understood that the lithographic apparatus
15 described herein may have other applications, such as the manufacture of integrated optical systems, guidance and detection patterns for magnetic domain memories, flat-panel displays, LCDs, thin-film magnetic heads, etc. The skilled artisan will appreciate that, in the context of such alternative applications, any use of the terms “wafer” or “die” herein may be considered as synonymous with the more general terms “substrate” or “target portion”, respectively. The
20 substrate referred to herein may be processed, before or after exposure, in for example a track unit (a tool that typically applies a layer of resist to a substrate and develops the exposed resist), a metrology unit and/or an inspection unit. Where applicable, the disclosure herein may be applied to such and other substrate processing tools. Further, the substrate may be processed more than once, for example in order to create a multi-layer IC, so that the term substrate used herein may
25 also refer to a substrate that already contains multiple processed layers.

[0097] Although specific reference may have been made above to the use of embodiments of the invention in the context of optical lithography, it will be appreciated that the invention may be used in other applications, for example imprint lithography, and where the context allows, is not limited to optical lithography. In imprint lithography a topography in a patterning device
30 defines the pattern created on a substrate. The topography of the patterning device may be pressed into a layer of resist supplied to the substrate whereupon the resist is cured by applying

electromagnetic radiation, heat, pressure or a combination thereof. The patterning device is moved out of the resist leaving a pattern in it after the resist is cured.

[0098] It is to be understood that the phraseology or terminology herein is for the purpose of description and not of limitation, such that the terminology or phraseology of the present specification is to be interpreted by those skilled in relevant art(s) in light of the teachings herein.

[0099] The term “substrate” as used herein describes a material onto which material layers are added. In some embodiments, the substrate itself may be patterned and materials added on top of it may also be patterned, or may remain without patterning.

[0100] 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 machine-readable medium may include read only memory (ROM); random access memory (RAM); magnetic disk storage media; optical storage media; flash memory devices; electrical, optical, acoustical, or other forms of propagated signals, and others. Further, firmware, software, routines, and/or instructions may be described herein as performing certain actions. However, it should be appreciated that such descriptions are merely for convenience and that such actions in fact result from computing devices, processors, controllers, or other devices executing the firmware, software, routines, and/or instructions.

[0101] The following examples are illustrative, but not limiting, of the embodiments of this disclosure. Other suitable modifications and adaptations of the variety of conditions and parameters normally encountered in the field, and which would be apparent to those skilled in the relevant art(s), are within the spirit and scope of the disclosure.

[0102] Although specific reference may be made in this text to the use of the apparatus and/or system according to the invention in the manufacture of ICs, it should be explicitly understood that such an apparatus and/or system has many other possible applications. For example, it can be employed in the manufacture of integrated optical systems, guidance and detection patterns for magnetic domain memories, LCD panels, thin-film magnetic heads, etc. The skilled artisan will appreciate that, in the context of such alternative applications, any use of the

terms “reticle,” “wafer,” or “die” in this text should be considered as being replaced by the more general terms “mask,” “substrate,” and “target portion,” respectively.

[0103] 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 description is not intended to limit the invention.

[0104] It is to be appreciated that the Detailed Description section, and not the Summary and Abstract sections, is intended to be used to interpret the claims. The Summary and Abstract sections may set forth one or more but not all exemplary embodiments of the present invention as contemplated by the inventor(s), and thus, are not intended to limit the present invention and the appended claims in any way.

[0105] The present invention has been described above with the aid of functional building blocks illustrating the implementation of specified functions and relationships thereof. The boundaries of these functional building blocks have been arbitrarily defined herein for the convenience of the description. Alternate boundaries can be defined so long as the specified functions and relationships thereof are appropriately performed.

[0106] The foregoing description of the specific embodiments will so fully reveal the general nature of the invention that others can, by applying knowledge within the skill of the art, readily modify and/or adapt for various applications such specific embodiments, without undue experimentation, without departing from the general concept of the present invention. Therefore, such adaptations and modifications are intended to be within the meaning and range of equivalents of the disclosed embodiments, based on the teaching and guidance presented herein.

[0107] The breadth and scope of the present invention should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.

CLAIMS

1. A safety device used to provide support for an object, comprising:
a driving side comprising a driving motor; and
5 a driven side comprising:
a housing comprising a rotating shaft extending along a length of the housing; and
a safety latch,
wherein the driven side is coupled to the driving motor via a non-contact, magnetic
coupling device at a first end of the rotating shaft,
10 wherein the safety latch is coupled to a second end of the rotating shaft opposite
from the first end of the rotating shaft, and
wherein the driving motor is configured to cause rotation in a radial direction of the
safety latch on the driving side via the non-contact, magnetic coupling device.
- 15 2. The safety device of claim 1, wherein:
the non-contact, magnetic coupling device comprises two components; and
a plurality of permanent magnets are arranged on the adjacent surfaces of the two
components and provide attractive forces between the two components of the magnetic coupling
device.
- 20 3. The safety device of claim 1, wherein the non-contact, magnetic coupling device comprises
a face to face coupling mechanism.
4. The safety device of claim 1, wherein the non-contact, magnetic coupling device comprises
25 a co-axial coupling mechanism.
5. The safety device of claim 1, wherein the safety latch is configured to rotate between a first
position and a second position, the first position and the second position being separated by angle
between about 5 degrees and about 20 degrees.

6. The safety device of claim 1, wherein the driving motor comprises a piezoelectric motor or a bi-stable DC motor.

7. The safety device of claim 1, wherein the safety latch comprises a foot portion at a distal end of the safety latch away from the rotating shaft, the foot portion being configured to act as a contact point for the object.

8. A lithographic apparatus, comprising:

an illumination system configured to condition a radiation beam;

a support structure constructed to support a patterning device, the patterning device being capable of imparting the radiation beam with a pattern in its cross-section to form a patterned radiation beam;

a projection system configured to project the patterned radiation beam onto a target portion of a substrate; and

one or more safety devices coupled to the support structure, each of the one or more safety devices comprising:

a driving side comprising a driving motor; and

a driven side comprising:

a housing comprising a rotating shaft extending along a length of the housing; and

a safety latch,

wherein the driven side is coupled to the driving motor via a non-contact, magnetic coupling device at a first end of the rotating shaft,

wherein the safety latch is coupled to a second end of the rotating shaft opposite from the first end of the rotating shaft, and

wherein the driving motor is configured to cause rotation in a radial direction of the safety latch on the driving side via the non-contact, magnetic coupling device.

9. The lithographic apparatus of claim 8, wherein:

non-contact, magnetic coupling device comprises two components; and

a plurality of permanent magnets are arranged on the adjacent surfaces of the two components and provide attractive forces between the two components of the magnetic coupling device.

5 10. The lithographic apparatus of claim 8, wherein the non-contact, magnetic coupling device comprises a face to face coupling mechanism.

11. The lithographic apparatus of claim 8, wherein the non-contact, magnetic coupling device comprises a co-axial coupling mechanism.

10

12. The lithographic apparatus of claim 8, wherein the safety latch is configured to rotate between a first position and a second position, the first position and the second position being separated by angle between about 5 degrees and about 20 degrees.

15 13. The lithographic apparatus of claim 8, wherein the driving motor comprises a piezoelectric motor or a bi-stable DC motor.

14. The lithographic apparatus of claim 8, wherein the safety latch comprises a foot portion at a distal end of the safety latch away from the rotating shaft, the foot portion being configured to
20 act as a contact point for the patterning device.

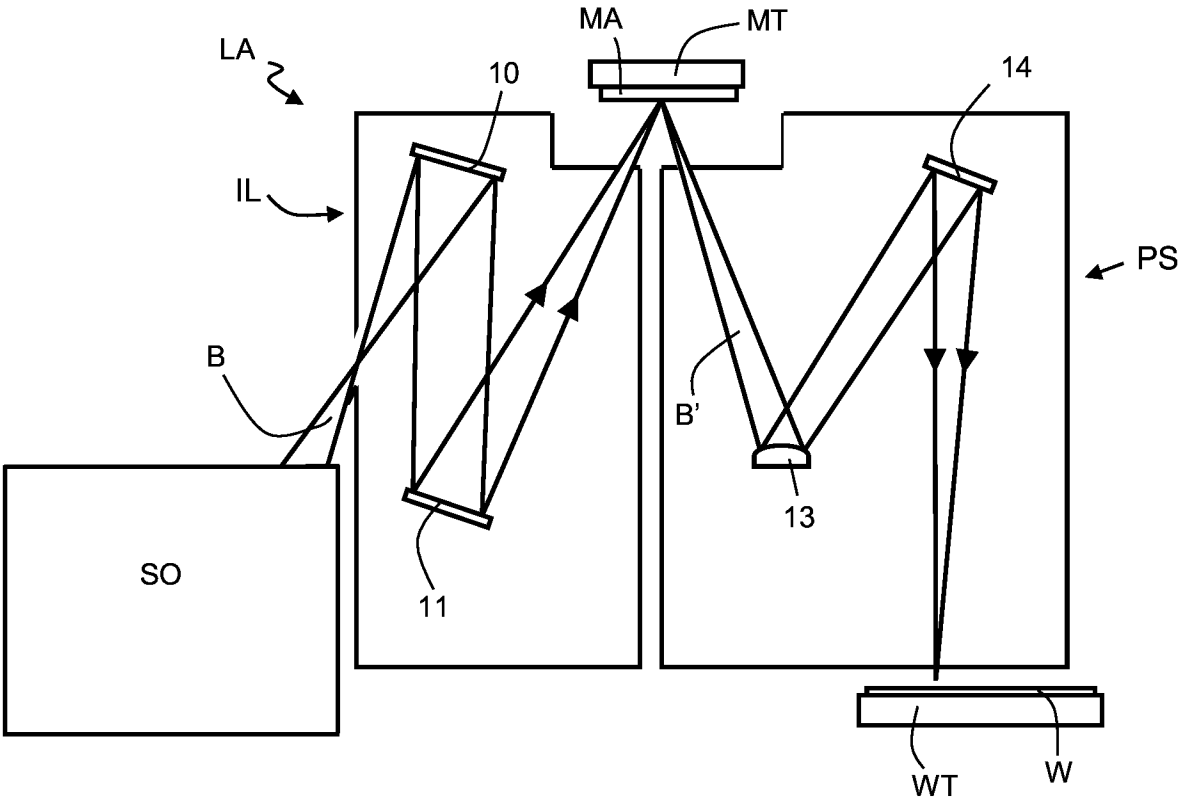


FIG. 1

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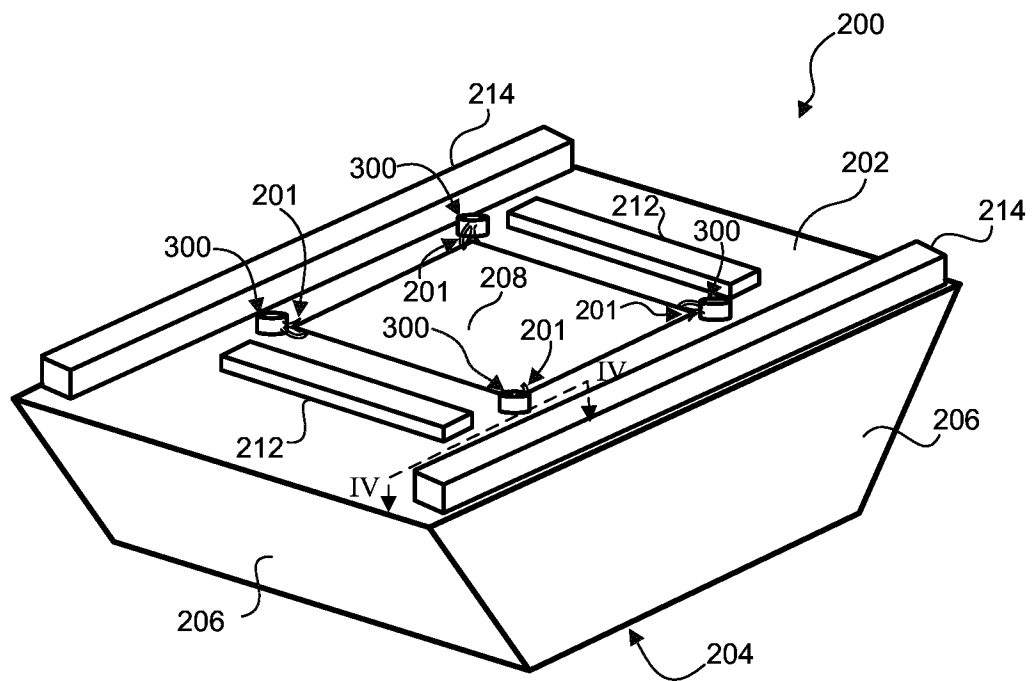


FIG. 2

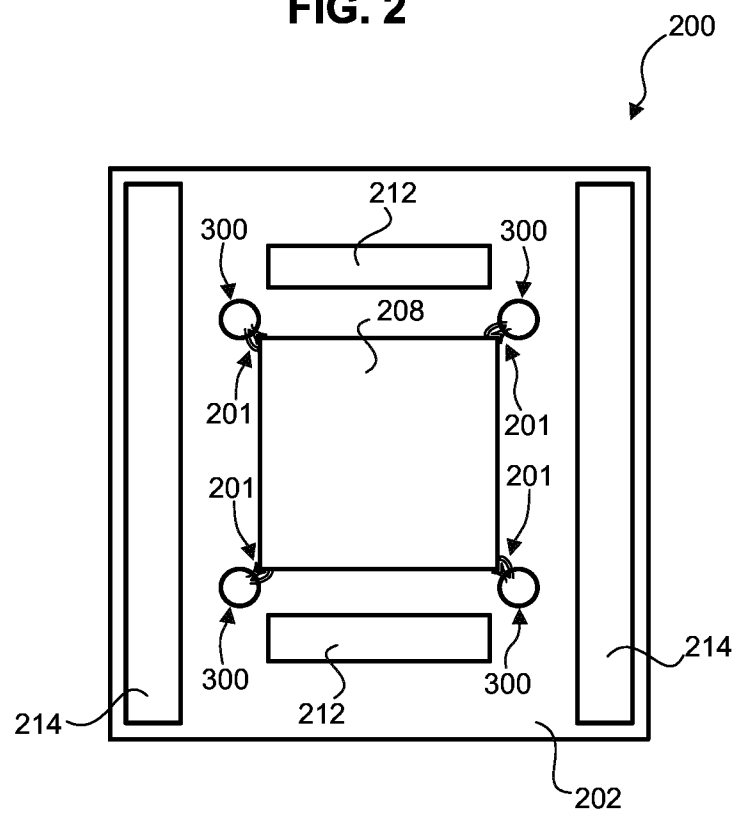


FIG. 3

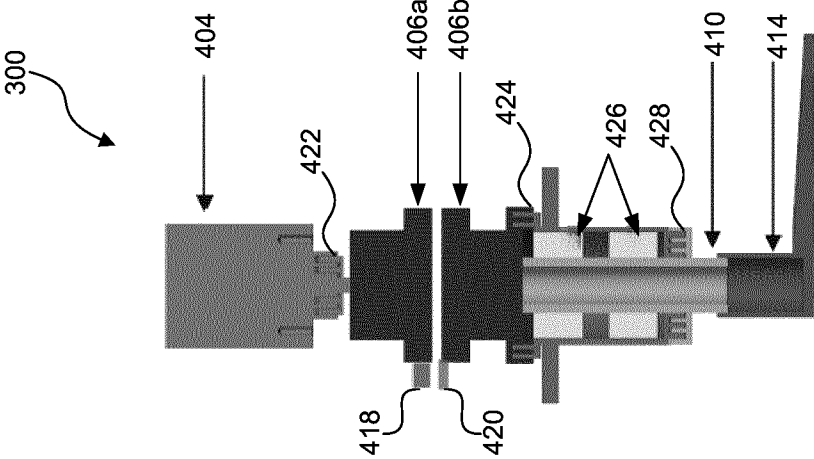
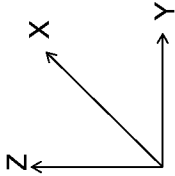


FIG. 4B

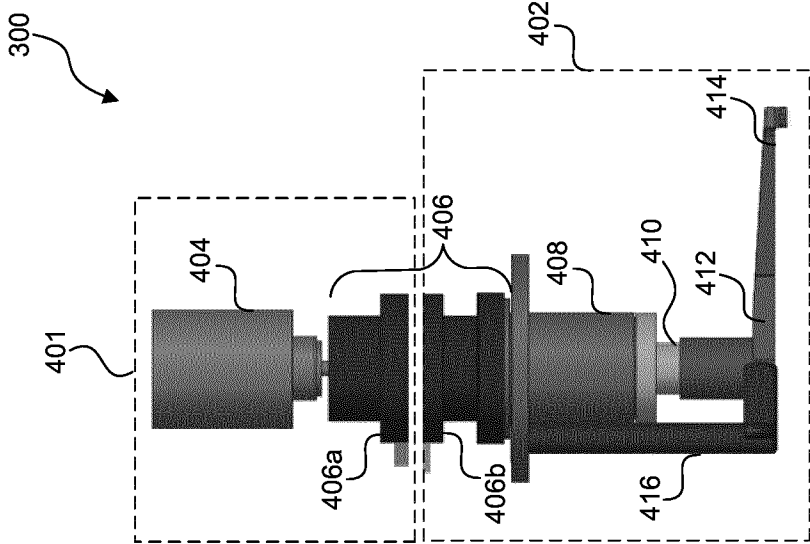


FIG. 4A

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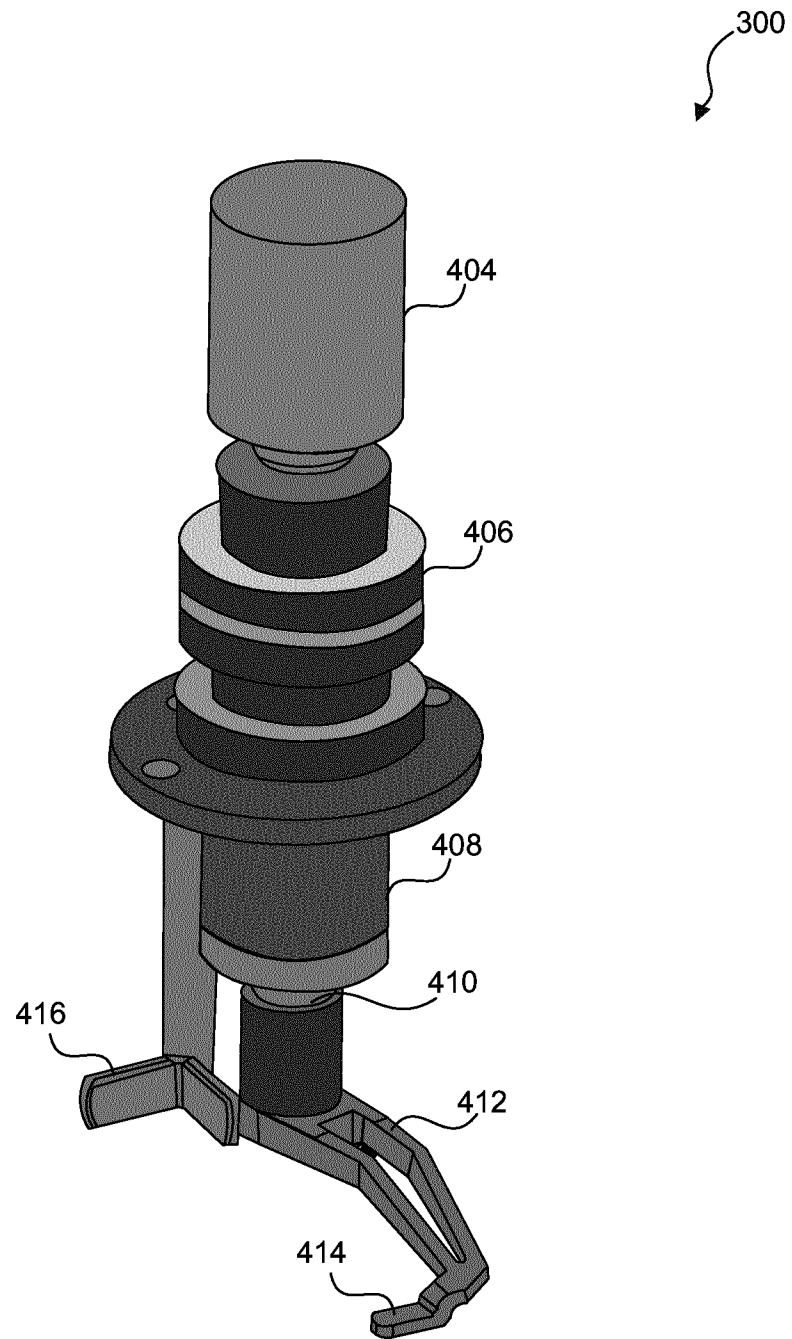


FIG. 5

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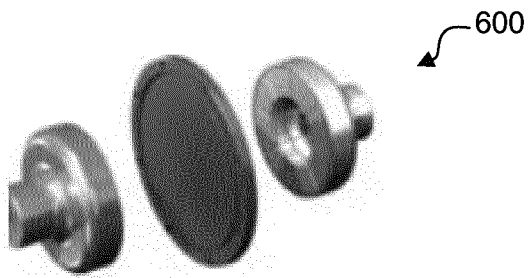


FIG. 6A

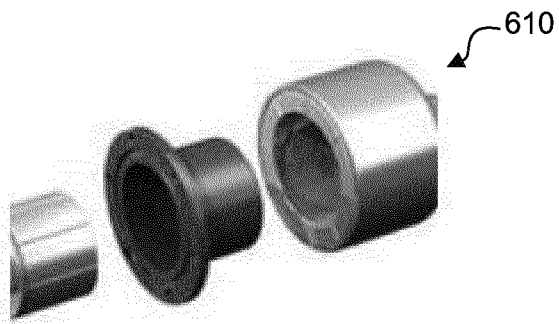


FIG. 6B

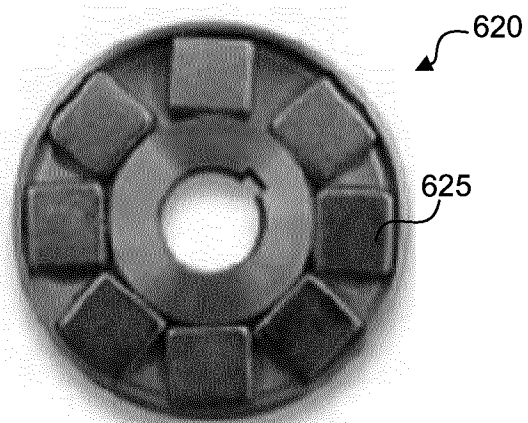


FIG. 6C

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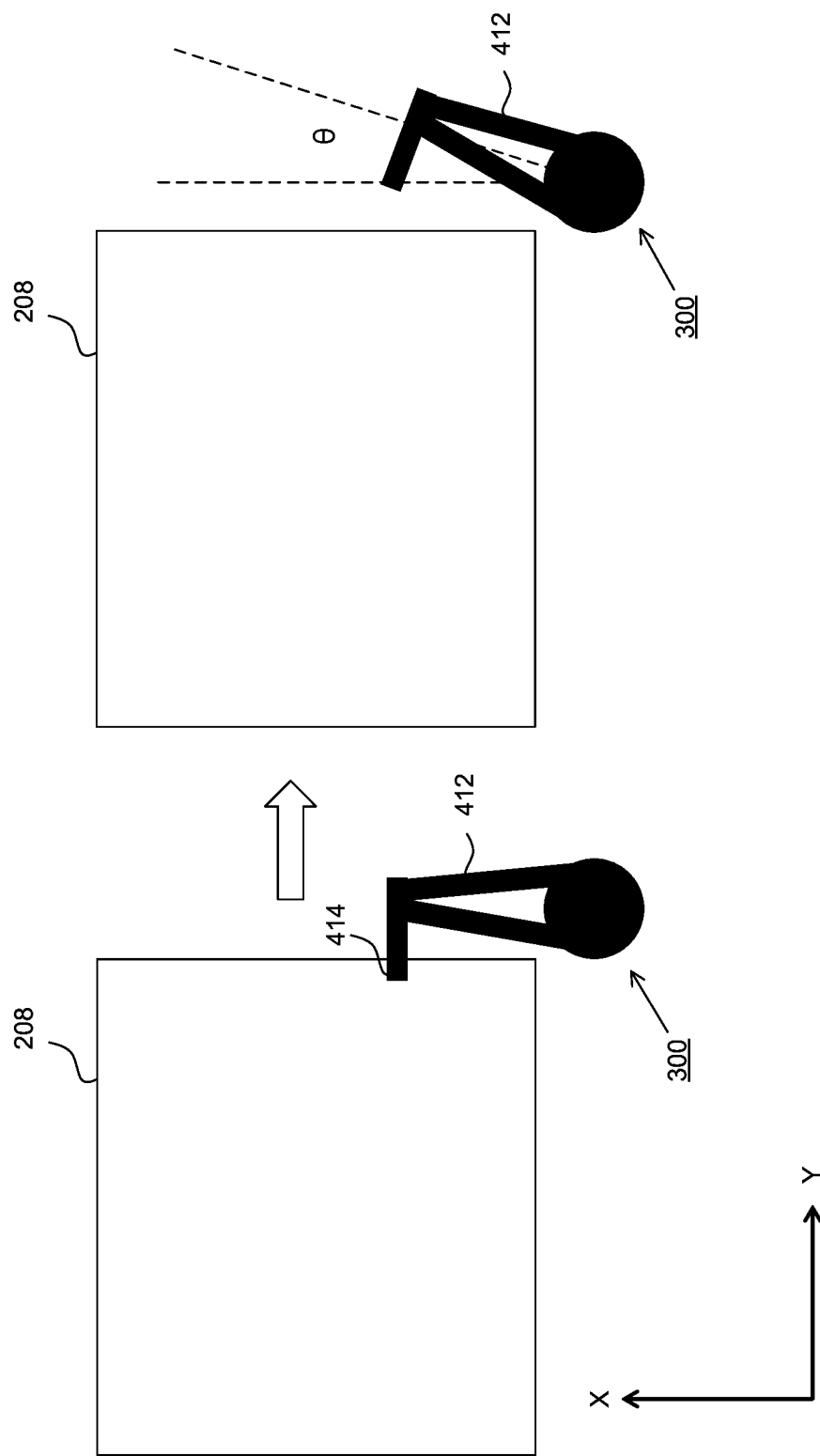


FIG. 7

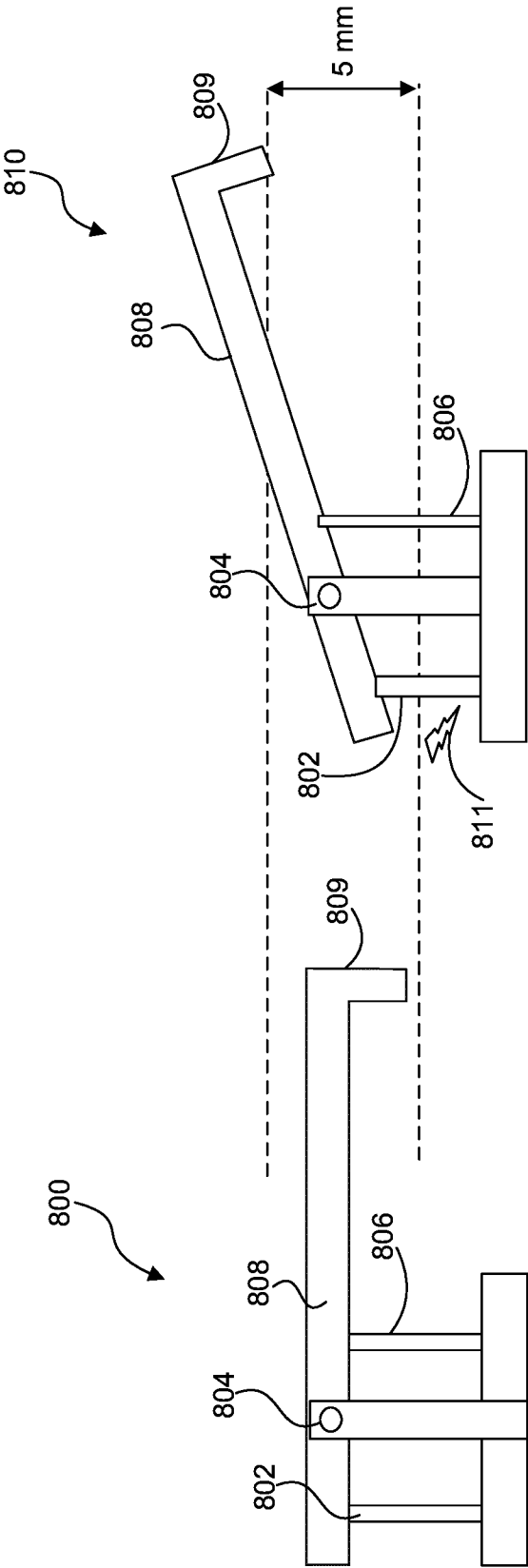


FIG. 8B

FIG. 8A

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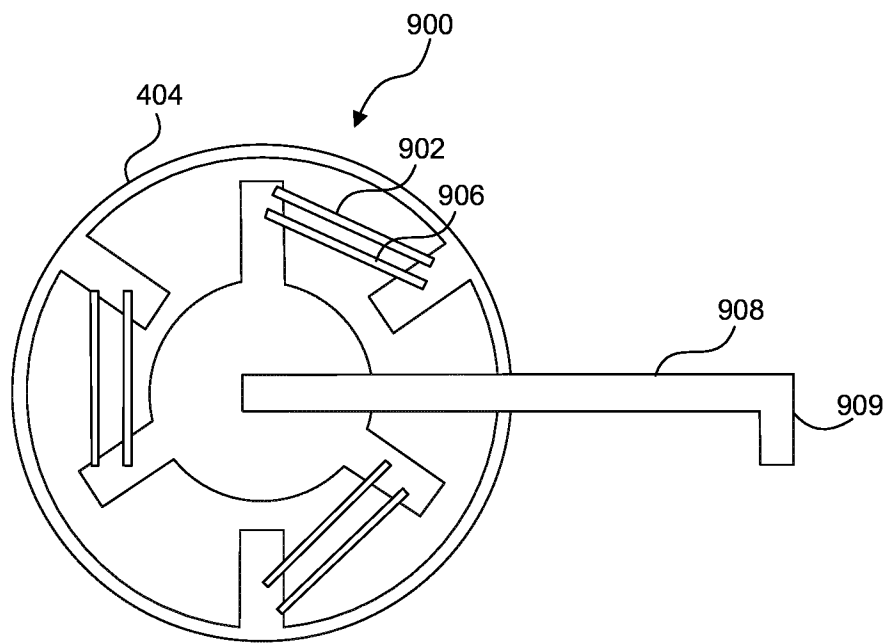


FIG. 9A

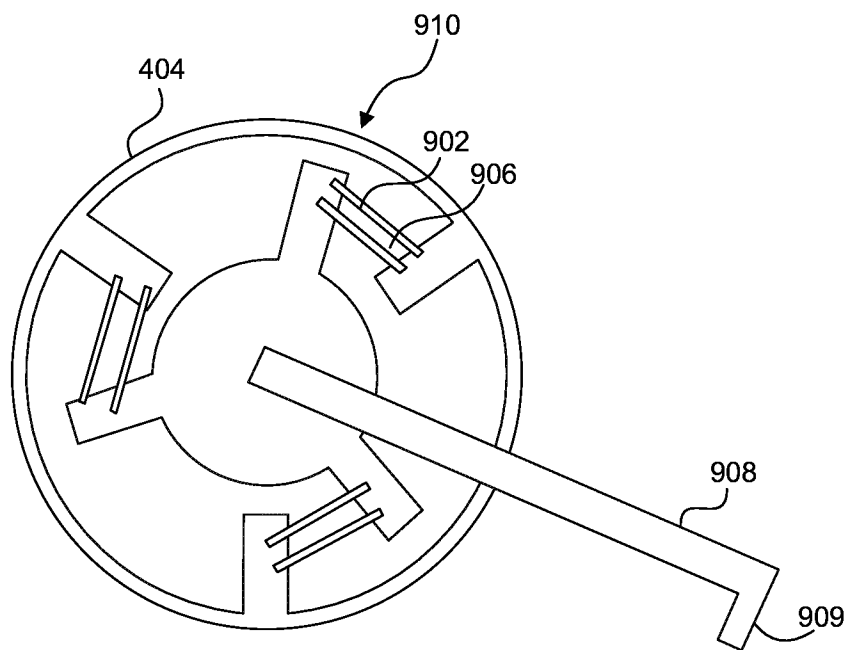


FIG. 9B

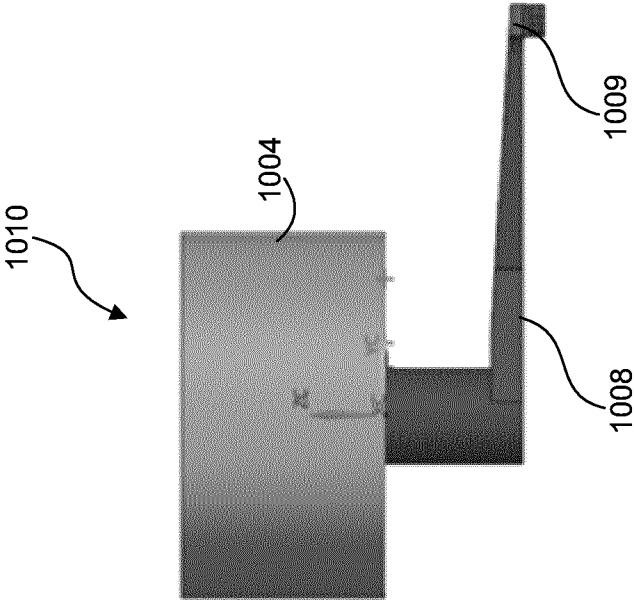


FIG. 10B

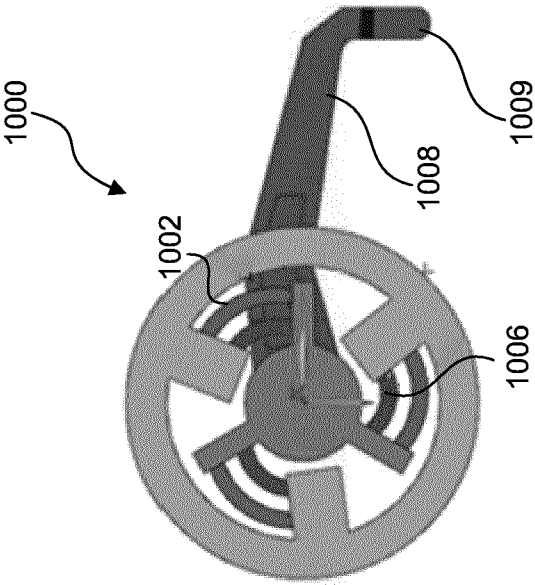


FIG. 10A

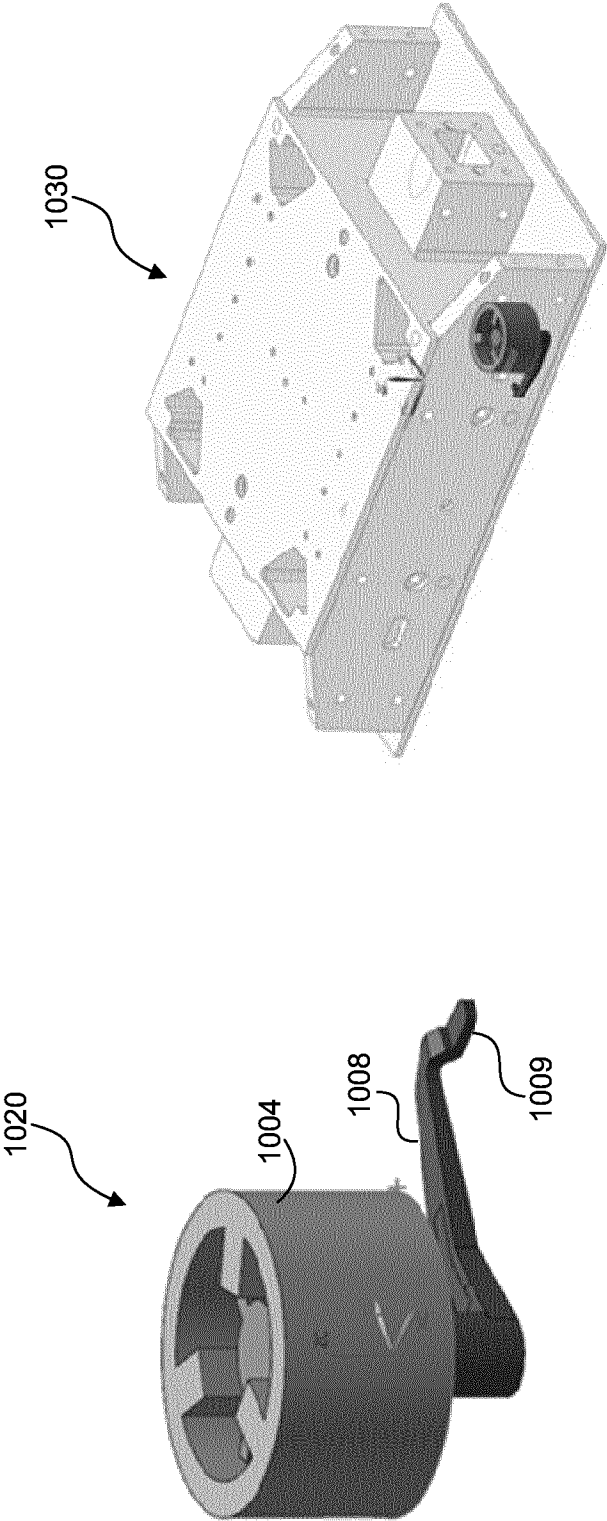
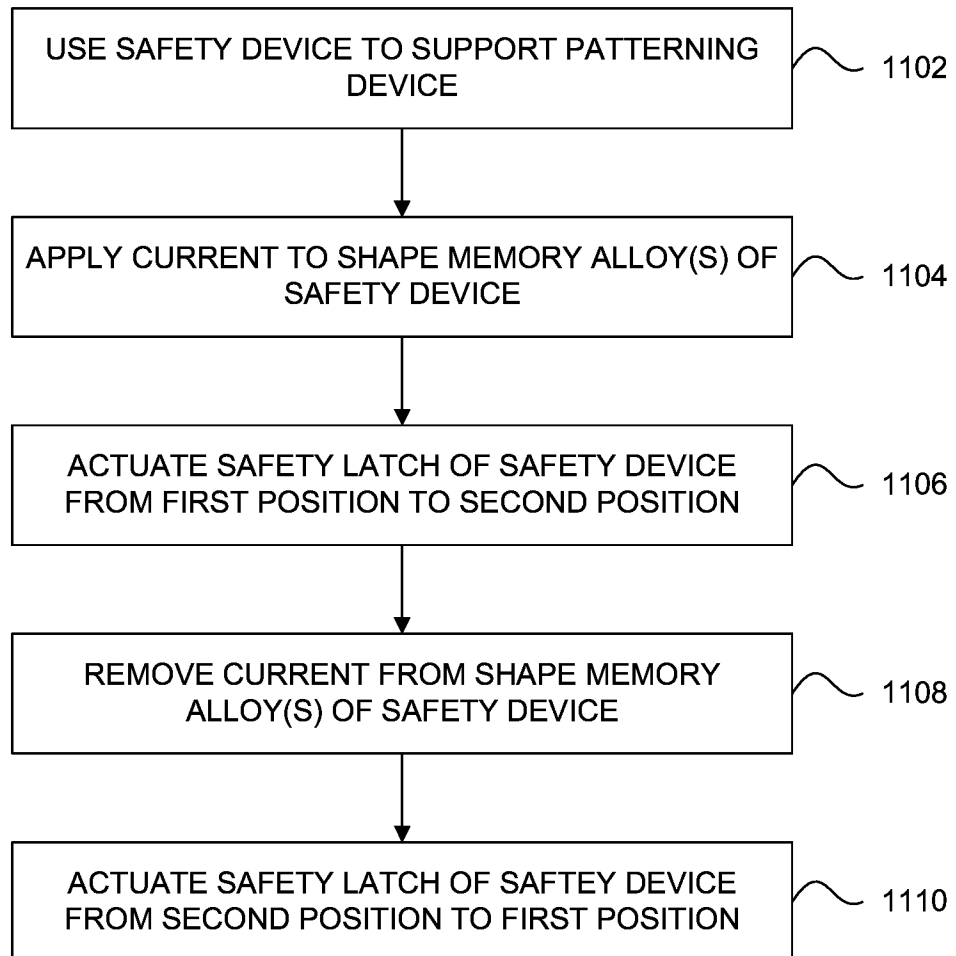


FIG. 10D

FIG. 10C

11/11

1100**FIG. 11**

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2020/061679

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

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

B. FIELDS SEARCHED

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

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	"EUV Reticle Safety Catch with Z-stroke", RESEARCH DISCLOSURE, KENNETH MASON PUBLICATIONS, HAMPSHIRE, UK, GB, vol. 638, no. 24, 1 June 2017 (2017-06-01) , page 482, XP007145646, ISSN: 0374-4353 [retrieved on 2017-05-11] the whole document -----	1-14
A	US 5 681 638 A (KORENAGA NOBUSHIGE [JP]) 28 October 1997 (1997-10-28) column 3, line 62 - column 4, line 23; figure 2 column 4, line 56 - column 5, line 2; figure 4 ----- -/--	1-14



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

24 July 2020

Date of mailing of the international search report

06/08/2020

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Authorized officer

Weckesser, Jens

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2020/061679

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 6 172 738 B1 (KORENAGA NOBUSHIGE [JP] ET AL) 9 January 2001 (2001-01-09) column 10, line 30 - column 12, line 33; figures 10, 11 -----	1-14
A	US 2002/167122 A1 (MERON OVADIA [US] ET AL) 14 November 2002 (2002-11-14) paragraphs [0035] - [0047]; figure 5 -----	1-14

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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			TW 405161 B 11-09-2000
		US 6172738 B1	09-01-2001

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			US 2002167122 A1 14-11-2002
		WO 03094210 A1	13-11-2003
