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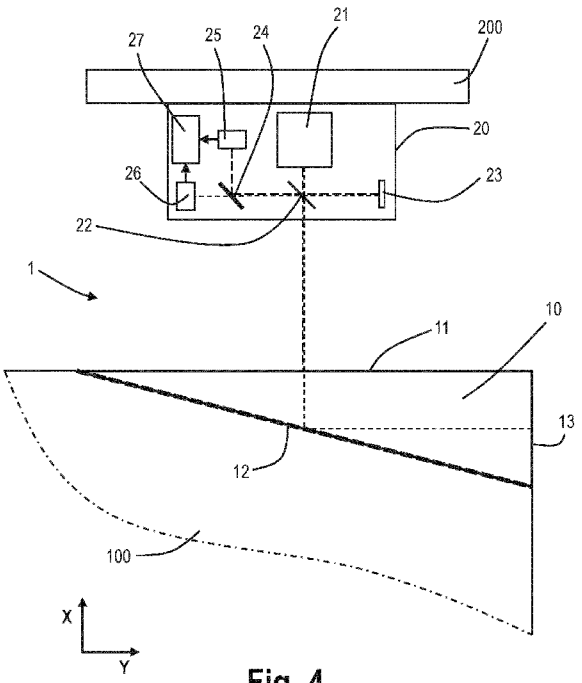


Fig. 4

(57) Abstract: Position measurement system to measure a position of a movable object in first and second orthogonal measurement directions, comprising light source to provide first and second measurement beams, interferometer optics to emit first and second measurement beams in first measurement direction, a first reflective target surface perpendicular to first measurement direction and arranged to reflect first measurement beam, a second reflective target surface perpendicular to second measurement direction, a grating positioned at non-45 degree angle relative to first reflective target surface and to provide a diffracted second measurement beam in second measurement direction using a diffraction order of the second measurement beam, providing a double diffracted second measurement beam in first measurement direction using a diffraction order of diffracted second measurement reflected on second reflective surface, a detector to receive the first measurement beam reflected on the first reflective target surface and to receive the double diffracted second measurement beam.

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POSITION MEASUREMENT SYSTEM, SUBSTRATE POSITIONING SYSTEM, LITHOGRAPHIC APPARATUS AND METHOD TO MEASURE A POSITION OF A MOVABLE OBJECT

CROSS-REFERENCE TO RELATED APPLICATION

[0001] The application claims priority of EP application 23178333.3 which was filed on 9 June, 2023 and EP application 23183210.6 which was filed on 4 July, 2023, and which are incorporated herein in their entirety by reference.

FIELD

[0002] The present invention relates to a position measurement system to measure a position of a movable object in at least first and second orthogonal measurement directions. The invention further relates to a substrate positioning system comprising the position measurement system and to a lithographic apparatus having such a substrate positioning system. The invention also relates to a method of measuring a position of a movable object in at least first and second orthogonal measurement directions.

BACKGROUND

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

[0004] As semiconductor manufacturing processes continue to advance, the dimensions of circuit elements have continually been reduced while the amount of functional elements, such as transistors, per device has been steadily increasing over decades, following a trend commonly referred to as 'Moore's law'. To keep up with Moore's law the semiconductor industry is chasing technologies that enable to create increasingly smaller features. To project a pattern on a substrate a lithographic apparatus may use electromagnetic radiation. The wavelength of this radiation determines the minimum size of features which are patterned on the substrate. Typical wavelengths currently in use are 365 nm (i-line), 248 nm, 193 nm and 13.5 nm. A lithographic apparatus, which uses extreme ultraviolet (EUV) radiation, having a wavelength within a range of 4 nm to 20 nm, for example 6.7 nm or 13.5 nm, may be used to form smaller features on a substrate than a lithographic apparatus which uses, for example, radiation with a wavelength of 193 nm.

[0005] To accurately align the position of the substrate with a radiation beam of the lithographic apparatus, the substrate may be supported on a movable substrate support. A position control system may be provided to accurately control the position of the movable substrate support. As part of the

position control system a position measurement system is provided to measure the position of the substrate support.

[0006] In a known embodiment of a position measurement system an interferometer system is used to measure a displacement of the movable substrate support. The interferometer system comprises a light source mounted on a reference object and configured to provide a measurement beam propagating in the measurement direction towards a reflective target surface mounted on the substrate support. The reflective target surface is a flat surface perpendicular to the measurement direction. The reflected measurement beam is combined with a reference beam that originates from the same light source such that the measurement beam and reference beam may interfere with each other. The combined measurement beam and reference beam are guided to a detector. On the basis of a detector signal provided by the detector a processing unit may determine a displacement of the substrate support with respect to the reference object.

[0007] Multiple of these position measurement systems may be provided to measure the position of the movable object in multiple degrees of freedom, for example six degrees of freedom.

[0008] A drawback of the known interferometer position measurement system is that the measurement direction is defined by the direction in which the measurement beam propagates from the reference object to the reflective target surface on the substrate support, or vice versa.

[0009] In some lithographic apparatuses or other substrate processing devices, multiple substrate supports may be provided next to each other with the result that in a respective measurement direction the light path to the reflective target surface on one substrate support may be blocked by a second substrate support, i.e. no direct line for propagation of the measurement beam from the reference object to the reflective target surface in the measurement direction is possible. In such lithographic apparatus or other substrate processing device, the interferometer based position measurement systems as described above cannot be applied.

SUMMARY

[0010] It is an object of the invention to provide a position measurement system that is capable of measuring a position of a movable object in a measurement direction without requiring a measurement beam propagating between the object of interest and the reference object in this measurement direction.

[0011] It is a further object of the invention to provide a substrate positioning system comprising such a position measurement system

[0012] According to an aspect of the invention, there is provided a position measurement system to measure a position of a movable object in at least a first measurement direction and a second measurement direction, wherein the first and second measurement directions are orthogonal to each other, comprising:

at least one light source to provide a first measurement beam and a second measurement beam,

interferometer optics to emit the first measurement beam and the second measurement beam in the first measurement direction,

a first reflective target surface perpendicular to the first measurement direction and arranged to reflect the first measurement beam,

a second reflective target surface perpendicular to the second measurement direction,

a grating positioned at a non-45 degree angle relative to the first reflective target surface and arranged to provide a diffracted second measurement beam in the second measurement direction using a first or higher order diffraction of the second measurement beam, wherein the grating is further arranged to provide a double diffracted second measurement beam in the first measurement direction using a first or higher order diffraction of the diffracted second measurement reflected on the second reflective surface, and

at least one detector arranged to receive the first measurement beam reflected on the first reflective target surface and to receive the double diffracted second measurement beam.

[0013] According to an aspect of the invention, there is provided a substrate positioning system comprising one or more movable substrate supports and one or more position measurement systems to measure the position of the one or more movable substrate supports in the first measurement direction and the second measurement direction.

[0014] According to an aspect of the invention, there is provided a lithographic apparatus comprising the substrate positioning system.

[0015] According to an aspect of the invention, there is provided a method of measuring a position of a movable object in at least a first measurement direction and a second measurement direction, wherein the first and second measurement directions are orthogonal to each other, the method comprising:

providing a first measurement beam and a second measurement beam propagating in the first measurement direction,

reflecting the first measurement beam on a first reflective target surface arranged perpendicular to the first measurement direction,

using a grating positioned at a non-45 degree angle relative to the first reflective target surface and arranged to provide a diffracted second measurement beam in the second measurement direction using a first or higher order diffraction of the second measurement beam,

reflecting the diffracted second measurement beam on a second reflective target surface arranged perpendicular to the second measurement direction,

using the grating to provide a double diffracted second measurement beam in the first measurement direction using a first or higher order diffraction of the diffracted second measurement reflected on the second reflective surface, and

measuring the first measurement beam reflected on the first reflective surface and the double diffracted second measurement beam.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] Embodiments of the invention will now be described, by way of example only, with reference to the accompanying schematic drawings, in which:

- Figure 1 depicts a schematic overview of a lithographic apparatus;
- Figure 2 depicts a detailed view of a part of the lithographic apparatus of Figure 1;
- Figure 3 schematically depicts a position control system;
- Figure 4 schematically depicts a first embodiment of a position measurement system according to the invention;
- Figure 5 schematically depicts a second embodiment of a position measurement system according to the invention; and
- Figure 6 schematically depicts a substrate support positioning system comprising embodiments of the position measurement according to the invention.

DETAILED DESCRIPTION

[0017] In the present document, the terms "radiation" and "beam" are used to encompass all types of electromagnetic radiation, including ultraviolet radiation (e.g. with a wavelength of 365, 248, 193, 157 or 126 nm) and EUV (extreme ultra-violet radiation, e.g. having a wavelength in the range of about 5-100 nm).

[0018] The term "reticle", "mask" or "patterning device" as employed in this text may be broadly interpreted as referring to a generic patterning device that can be used to endow an incoming radiation beam with a patterned cross-section, corresponding to a pattern that is to be created in a target portion of the substrate. The term "light valve" can also be used in this context. Besides the classic mask (transmissive or reflective, binary, phase-shifting, hybrid, etc.), examples of other such patterning devices include a programmable mirror array and a programmable LCD array.

[0019] Figure 1 schematically depicts a lithographic apparatus LA. The lithographic apparatus LA includes an illumination system (also referred to as illuminator) IL configured to condition a radiation beam B (e.g., UV radiation, DUV radiation or EUV radiation), a mask support (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 MA in accordance with certain parameters, a substrate support (e.g., a wafer table) WT constructed to hold a substrate (e.g., a resist coated wafer) W and connected to a second positioner PW configured to accurately position the substrate support in accordance with certain parameters, and a projection system (e.g., a refractive 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.

[0020] In operation, the illumination system IL receives a radiation beam from a radiation source SO, e.g. via a beam delivery system BD. The illumination system IL may include various types of

optical components, such as refractive, reflective, magnetic, electromagnetic, electrostatic, and/or other types of optical components, or any combination thereof, for directing, shaping, and/or controlling radiation. The illuminator IL may be used to condition the radiation beam B to have a desired spatial and angular intensity distribution in its cross section at a plane of the patterning device MA.

[0021] The term "projection system" PS used herein should be broadly interpreted as encompassing various types of projection system, including refractive, reflective, catadioptric, anamorphic, magnetic, electromagnetic and/or electrostatic optical systems, or any combination thereof, as appropriate for the exposure radiation being used, and/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" PS.

[0022] The lithographic apparatus LA may be of a type wherein at least a portion of the substrate may be covered by a liquid having a relatively high refractive index, e.g., water, so as to fill a space between the projection system PS and the substrate W – which is also referred to as immersion lithography. More information on immersion techniques is given in US6952253, which is incorporated herein by reference.

[0023] The lithographic apparatus LA may also be of a type having two or more substrate supports WT (also named "dual stage"). In such "multiple stage" machine, the substrate supports WT may be used in parallel, and/or steps in preparation of a subsequent exposure of the substrate W may be carried out on the substrate W located on one of the substrate support WT while another substrate W on the other substrate support WT is being used for exposing a pattern on the other substrate W.

[0024] In addition to the substrate support WT, the lithographic apparatus LA may comprise a measurement stage. The measurement stage is arranged to hold a sensor and/or a cleaning device. The sensor may be arranged to measure a property of the projection system PS or a property of the radiation beam B. The measurement stage may hold multiple sensors. The cleaning device may be arranged to clean part of the lithographic apparatus, for example a part of the projection system PS or a part of a system that provides the immersion liquid. The measurement stage may move beneath the projection system PS when the substrate support WT is away from the projection system PS.

[0025] In operation, the radiation beam B is incident on the patterning device, e.g. mask, MA which is held on the mask support MT, and is patterned by the pattern (design layout) present on patterning device MA. 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 a position measurement system PMS, the substrate support WT can be moved accurately, e.g., so as to position different target portions C in the path of the radiation beam B at a focused and aligned position. Similarly, the first positioner PM and possibly another position sensor (which is not explicitly depicted in Figure 1) may be used to accurately position the patterning device MA with respect to the path of the radiation beam B. Patterning device

MA and substrate W may be aligned using mask alignment marks M1, M2 and substrate alignment marks P1, P2. Although the substrate alignment marks P1, P2 as illustrated occupy dedicated target portions, they may be located in spaces between target portions. Substrate alignment marks P1, P2 are known as scribe-lane alignment marks when these are located between the target portions C.

[0026] To clarify the invention, a Cartesian coordinate system is used. The Cartesian coordinate system has three axes, i.e., an x-axis, a y-axis and a z-axis. Each of the three axes is orthogonal to the other two axes. A rotation around the x-axis is referred to as an Rx-rotation. A rotation around the y-axis is referred to as an Ry-rotation. A rotation around about the z-axis is referred to as an Rz-rotation. The x-axis and the y-axis define a horizontal plane, whereas the z-axis is in a vertical direction. The Cartesian coordinate system is not limiting the invention and is used for clarification only. Instead, another coordinate system, such as a cylindrical coordinate system, may be used to clarify the invention. The orientation of the Cartesian coordinate system may be different, for example, such that the z-axis has a component along the horizontal plane.

[0027] Figure 2 shows a more detailed view of a part of the lithographic apparatus LA of Figure 1. The lithographic apparatus LA may be provided with a base frame BF, a balance mass BM, a metrology frame MF and a vibration isolation system IS. The metrology frame MF supports the projection system PS. Additionally, the metrology frame MF may support a part of the position measurement system PMS. The metrology frame MF is supported by the base frame BF via the vibration isolation system IS. The vibration isolation system IS is arranged to prevent or reduce vibrations from propagating from the base frame BF to the metrology frame MF.

[0028] The second positioner PW is arranged to accelerate the substrate support WT by providing a driving force between the substrate support WT and the balance mass BM. The driving force accelerates the substrate support WT in a desired direction. Due to the conservation of momentum, the driving force is also applied to the balance mass BM with equal magnitude, but at a direction opposite to the desired direction. Typically, the mass of the balance mass BM is significantly larger than the masses of the moving part of the second positioner PW and the substrate support WT.

[0029] In an embodiment, the second positioner PW is supported by the balance mass BM. For example, wherein the second positioner PW comprises a planar motor to levitate the substrate support WT above the balance mass BM. In another embodiment, the second positioner PW is supported by the base frame BF. For example, wherein the second positioner PW comprises a linear motor and wherein the second positioner PW comprises a bearing, like a gas bearing, to levitate the substrate support WT above the base frame BF.

[0030] The position measurement system PMS may comprise any type of sensor that is suitable to determine a position of the substrate support WT. The position measurement system PMS may comprise any type of sensor that is suitable to determine a position of the mask support MT. The sensor may be an optical sensor such as an interferometer or an encoder. The position measurement system PMS may comprise a combined system of an interferometer and an encoder. The sensor may

be another type of sensor, such as a magnetic sensor. a capacitive sensor or an inductive sensor. The position measurement system PMS may determine the position relative to a reference, for example the metrology frame MF or the projection system PS. The position measurement system PMS may determine the position of the substrate table WT and/or the mask support MT by measuring the position or by measuring a time derivative of the position, such as velocity or acceleration.

[0031] The position measurement system PMS may comprise an interferometer system. An interferometer system is known from, for example, United States patent US6,020,964, filed on July 13, 1998, hereby incorporated by reference. The interferometer system may comprise a beam splitter, a mirror, a reference mirror and a sensor. A beam of radiation is split by the beam splitter into a reference beam and a measurement beam. The measurement beam propagates to the mirror and is reflected by the mirror back to the beam splitter. The reference beam propagates to the reference mirror and is reflected by the reference mirror back to the beam splitter. At the beam splitter, the measurement beam and the reference beam are combined into a combined radiation beam. The combined radiation beam is incident on the sensor. The sensor determines a phase or a frequency of the combined radiation beam. The sensor generates a signal based on the phase or the frequency. The signal is representative of a displacement of the mirror. In an embodiment, the mirror is connected to the substrate support WT. The reference mirror may be connected to the metrology frame MF. In an embodiment, the measurement beam and the reference beam are combined into a combined radiation beam by an additional optical component instead of the beam splitter.

[0032] The first positioner PM may comprise a long-stroke module and a short-stroke module. The short-stroke module is arranged to move the mask support MT relative to the long-stroke module with a high accuracy over a small range of movement. The long-stroke module is arranged to move the short-stroke module relative to the projection system PS with a relatively low accuracy over a large range of movement. With the combination of the long-stroke module and the short-stroke module, the first positioner PM is able to move the mask support MT relative to the projection system PS with a high accuracy over a large range of movement. Similarly, the second positioner PW may comprise a long-stroke module and a short-stroke module. The short-stroke module is arranged to move the substrate support WT relative to the long-stroke module with a high accuracy over a small range of movement. The long-stroke module is arranged to move the short-stroke module relative to the projection system PS with a relatively low accuracy over a large range of movement. With the combination of the long-stroke module and the short-stroke module, the second positioner PW is able to move the substrate support WT relative to the projection system PS with a high accuracy over a large range of movement.

[0033] The first positioner PM and the second positioner PW each are provided with an actuator to move respectively the mask support MT and the substrate support WT. The actuator may be a linear actuator to provide a driving force along a single axis, for example the y-axis. Multiple linear actuators may be applied to provide driving forces along multiple axis. The actuator may be a planar

actuator to provide a driving force along multiple axis. For example, the planar actuator may be arranged to move the substrate support WT in 6 degrees of freedom. The actuator may be an electro-magnetic actuator comprising at least one coil and at least one magnet. The actuator is arranged to move the at least one coil relative to the at least one magnet by applying an electrical current to the at least one coil. The actuator may be a moving-magnet type actuator, which has the at least one magnet coupled to the substrate support WT respectively to the mask support MT. The actuator may be a moving-coil type actuator which has the at least one coil coupled to the substrate support WT respectively to the mask support MT. The actuator may be a voice-coil actuator, a reluctance actuator, a Lorentz-actuator or a piezo-actuator, or any other suitable actuator.

[0034] The lithographic apparatus LA comprises a position control system PCS as schematically depicted in Figure 3. The position control system PCS comprises a setpoint generator SP, a feedforward controller FF and a feedback controller FB. The position control system PCS provides a drive signal to the actuator ACT. The actuator ACT may be the actuator of the first positioner PM or the second positioner PW. The actuator ACT drives the plant P, which may comprise the substrate support WT or the mask support MT. An output of the plant P is a position quantity such as position or velocity or acceleration. The position quantity is measured with the position measurement system PMS. The position measurement system PMS generates a signal, which is a position signal representative of the position quantity of the plant P. The setpoint generator SP generates a signal, which is a reference signal representative of a desired position quantity of the plant P. For example, the reference signal represents a desired trajectory of the substrate support WT. A difference between the reference signal and the position signal forms an input for the feedback controller FB. Based on the input, the feedback controller FB provides at least part of the drive signal for the actuator ACT. The reference signal may form an input for the feedforward controller FF. Based on the input, the feedforward controller FF provides at least part of the drive signal for the actuator ACT. The feedforward FF may make use of information about dynamical characteristics of the plant P, such as mass, stiffness, resonance modes and eigenfrequencies.

[0035] Figure 4 shows an embodiment of a bi-directional position measurement system 1. The position measurement system 1 is arranged to measure the position of a movable object 100 in a first measurement direction and a second measurement direction with respect to a reference object 200. The first measurement direction and the second measurement direction are orthogonal with respect to each other and indicated in Figure 4 as the x-direction and the y-direction.

[0036] The position measurement system 1 comprises an interferometer unit 20 mounted on the reference object 200 and a reflection element 10 mounted on the movable object 100. In an alternative embodiment, the interferometer unit 20 may be mounted on the movable object 100 and the reflection element 10 may be mounted on the reference object.

[0037] The interferometer unit 20 comprises a light source 21 to provide a first radiation beam and a second radiation beam, the first radiation beam having a first polarization and the second radiation beam having a second polarization, the first polarization being orthogonal to the second polarization.

[0038] A semi-transparent mirror 22 is provided to split the first radiation beam in a first measurement beam and a first reference beam and to split the second radiation beam in a second measurement beam and a second reference beam. Thus, the radiation beam provided by the light source 21 includes the first measurement beam, the second measurement beam, the first reference beam and the second reference beam. In an alternative embodiment, a first light source may provide a first radiation beam including the first measurement beam and the first reference beam and a second light source may provide a second radiation beam including the second measurement beam and the second reference beam

[0039] The first reference beam and the second reference beam are guided to a reference mirror 23.

[0040] The first measurement beam and the second measurement beam are emitted from the interferometer optics, in this embodiment the semi-transparent mirror 22, towards the reflection element 10.

[0041] The reflection element 10 is a transparent body having a wedge shape. The wedge shape is formed by a beam shaped object with a right-angled triangular cross-section. The reflection element 10 may be made of any material that is transparent for the second measurement beam, such as glass or transparent plastics material.

[0042] The reflection element 10 comprises a first reflective target surface 11, a grating 12 and a second reflective target surface 13. The grating 12 is arranged at a hypothenuse side of the right-angled triangular cross section, and the first reflective target surface 11 and the second reflective target surface 13 are arranged at the other two sides of the right-angled triangular cross section. The first reflective target surface 11, the grating 12 and the second reflective target surface 13 may be formed on or in the reflection element 10. As an alternative, the reflection element 10 may support first reflective target surface 11, the grating 12 and/or the second reflective target surface 13.

[0043] The grating 12 may be any suitable grating, for example a blazed angle grating.

[0044] The first reflective target surface 11 is arranged perpendicular to the first measurement direction (x-direction) and configured to reflect the first measurement beam and to transmit the second measurement beam. This division between the first measurement beam and the second measurement beam may be based on polarization, since the first measurement beam has the first polarization and the second measurement beam has the second polarization. The division may also be based on other characteristics or configurations, for example on a difference in wavelength between the first radiation beam and the second radiation beam.

[0045] The reflected first measurement beam will be received by the interferometer unit 20 and at least partially guided by the semi-transparent mirror 22 towards a polarization sensitive mirror 24. At the semi-transparent mirror 22 the reflected first measurement beam will be recombined with at least

part of the first reference beam reflected on the reference mirror 23. Interference between the first measurement beam and the first reference beam in this recombined beam is representative for displacement of the movable object 100 with respect to the reference object 200 in the x-direction.

[0046] The second measurement beam is transmitted by the first reflective target surface 11 such that it propagates in the first measurement direction (x-direction) through the reflection element 10 towards the grating 12. The grating 12 is arranged at a non-45 degree angle with respect to the first reflective target surface 11.

[0047] The grating 12 and its angle with respect to the first reflective target surface are selected such that a first order diffraction of the second measurement beam created by the grating 12 will propagate in the second measurement direction (y-direction) as a diffracted second measurement beam towards the second reflective target surface 13.

[0048] The second reflective target surface 13 is arranged perpendicular to the second measurement direction such that the diffracted second measurement beam will be reflected at right angles on the second reflective target surface 13 and the reflected diffracted second measurement beam will propagate in the second measurement direction back to the grating 12.

[0049] The grating 12 will reflect a first order diffraction of the diffracted second measurement beam, as a double diffracted second measurement beam that propagates in the first measurement direction. This double diffracted second measurement beam will propagate back to the interferometer unit 20 where it will be at least partially be reflected by the semi-transparent mirror 22 towards a polarization sensitive mirror 24.

[0050] At the semi-transparent mirror 22 the double diffracted second measurement beam will be recombined with at least part of the second reference beam reflected on the reference mirror 23. Interference between the double diffracted second measurement beam and the second reference beam in this recombined beam is representative for a displacement of the movable object 100 with respect to the reference object 200 in x-direction and/or y-direction.

[0051] The polarization sensitive mirror 24 is configured to reflect light having the first polarization and transmit light having the second polarization. As a result, the first measurement beam and the first reference beam will be reflected by the polarization sensitive mirror 24 and guided to a first detector 25, and the double diffracted second measurement beam and the second reference beam will be transmitted by the polarization sensitive mirror 24 and guided to a second detector 26.

[0052] On the basis of the recombined beam of first measurement beam and the first reference beam, the first detector 25 may provide a first interferometer signal representative for the change in length of a first measurement light path of the first measurement beam. Correspondingly, on the basis of the recombined beam of the double diffracted second measurement beam and the second reference beam, the second detector 26 may provide a second interferometer signal representative for a change in length of a second measurement light path of the second measurement beam, diffracted second measurement beam and the double diffracted second measurement beam.

[0053] The first measurement light path length extends in the first measurement direction. Therefore, the first interferometer signal is representative for displacement of the movable object 100 with respect to the reference object 200 in the x-direction. The second measurement light path runs both in x-direction and in y-direction. The second interferometer signal is therefore representative for displacement of the movable object 100 with respect to the reference object 200 in both the x-direction and the y-direction.

[0054] The first interferometer signal and the second interferometer signal are guided to a processing device 27 in which a change in the position of the movable object 100 with respect to the reference object 200 can be determined. The first interferometer signal can be used to determine a displacement of the movable object 100 in the x-direction. The combination of the first interferometer signal and the second interferometer signal can be used to determine a displacement of the movable object 100 in the y-direction.

[0055] It is noted that if the grating 12 would be a reflective surface at an angle of 45 degrees, the angle of the second measurement beam could be changed from the x-direction to the y-direction without the need of using diffractions of the second measurement beam. However, in such an embodiment a displacement of the movable object 100 in the y-direction would result in an increase in length of the second measurement light path in the x-direction or the y-direction but also an equal decrease in length of the second measurement light path in the other of the x-direction and y-direction. Thus, with such an embodiment, the movement of the movable object in the y-direction with respect to the reference object cannot be determined on the basis of a change in path length of the second measurement beam.

[0056] Using a configuration having a non-45 degrees grating 12 and using diffractions of the second measurement beam to reflect the second measurement beam from x-direction to y-direction and vice versa, measurement of displacement of the movable object 100 in the y-direction with a measurement beam propagating between the interferometer unit 20 and the reflection element 10 in the x-direction is enabled. This makes it possible to measure displacement of the movable object 100 in both the x-direction and y-direction from one side of the movable object 100.

[0057] Since the position measurement system 1 is capable of measuring a displacement of the movable object 100 in two orthogonal measurement directions using two measurement beams that both propagate between the reflection element 10 and the interferometer unit 20 in only one of the two measurement directions, the position measurement system 1 may be referred to as bi-directional position measurement system.

[0058] The ratio between a movement of the movable object 100 in the y-direction and a resulting change in light path length of the second measurement beam, diffracted second measurement beam and double diffracted second measurement beam is not necessarily 1:1, but will normally be above 1. This ratio may depend on the wavelength of the second measurement beam and on characteristics of

the grating 12, such as angle of the grating 12 with respect to the first reflective target surface 11 and the grating period of the grating 12.

[0059] Generally, the non-45 degrees angle of the grating 12 with respect to the first reflective target surface 11, may be in the range between 0 and 90 degrees, but not 45 degrees. An angle further away from 45 degrees, i.e. smaller than or larger than 45 degrees, will result in a lower ratio between a movement of the movable object 100 in the y-direction and a change in light path length of the second measurement beam, diffracted second measurement beam and double diffracted second measurement beam.

[0060] A relatively small angle of the grating 12 has the additional advantage that the reflection element 10 will take in a small volume on the movable object 100 since such angle also results in a smaller height of the second reflective target surface 13. The grating 12 may therefore be designed to have a relatively small angle with respect to the first reflective target surface 11, while at the same time providing an angle of 90 degrees between the second measurement beam and the first diffraction of the second measurement beam.

[0061] A relatively large angle of the grating 12 also has the advantage that the reflection element 10 will take in a smaller volume on the movable object 100, but will also result in a small measurement range in the y-direction which is defined by the length of the side of the triangular cross section where the first reflective target surface 11 is mounted.

[0062] In practice, the angle of the grating 12 with respect to the first reflective target surface 11 may for example be selected between 5 and 35 degrees, such as between 10 and 30 degrees. When a relatively small measurement range in the y-direction is acceptable, the angle of the grating 12 with respect to the first reflective target surface 11 may also for example be selected between 55 and 85 degrees, such as between 60 and 80 degrees.

[0063] The ratio between a movement of the movable object 100 in y-direction and a change in light path length of the second measurement beam, diffracted second measurement beam and double diffracted second measurement beam is also dependent on the refractive index of the material of the reflection element 10. By selecting in addition to the angle of the grating 12, the grating period of the grating 12 and the wavelength of the second measurement beam, a specific material, the ratio between a movement of the movable object 100 in y-direction and a change in light path length of the second measurement beam, diffracted second measurement beam and double diffracted second measurement beam may be made 1:1. It is also possible to further decrease the ratio to increase the sensitivity of the measurement in the y-direction even further.

[0064] In case a 1:1 ratio is not present the processing device 27 may compensate for this non 1:1 ratio when processing the second interferometer signal to calculate the position of the movable object 100 in y-direction.

[0065] Figure 5 shows an alternative embodiment of a bi-directional position measurement system 1. In this embodiment, the interferometer unit 20 comprises a first light source 21a to provide a first radiation beam and a second light source 21b to provide a second radiation beam.

[0066] At a first semi-transparent mirror 22a the first radiation beam is split in a first measurement beam and a first reference beam. The first reference beam is guided to a first reference mirror 23a. The first measurement beam propagates in a first measurement direction, e.g. the x-direction, towards a first reflective target surface 11 mounted on the movable object perpendicular to the first measurement direction. After reflection on the first reflective target surface 11 the reflected first measurement beam propagates back to the interferometer unit 20, where it is at least partially recombined with the reference beam reflected on the first reference mirror 23a. The recombined beam is guided to a first detector 25 to provide a first interferometer signal.

[0067] At a second semi-transparent mirror 22b the second radiation beam is split in a second measurement beam and a second reference beam. The second reference beam is guided to a second reference mirror 23b. The second measurement beam propagates in the first measurement direction, e.g. the x-direction, towards the movable object 100. The second measurement beam is transmitted through the first reflective target surface 11, for example due to a different polarizations of the first measurement beam and the second measurement beam. In other embodiments, the first reflective target surface may be arranged at a different level in the z-direction (perpendicular to the x-y plane) compared to the grating 12 and the second reflective target surface 13 or different wavelengths may be used for the first radiation beam and the second radiation beam.

[0068] The second measurement beam will be diffracted on the grating 12. The grating 12 is arranged to reflect a first diffraction of the second measurement beam in the second measurement direction, the y-direction, towards a second reflective target surface 13 arranged perpendicular to the second measurement direction and mounted on the movable object 100. The second reflective target surface 13 reflects the diffracted second measurement beam back to the grating 12. The grating 12 will reflect a first order diffraction of the second measurement beam that will propagate, as a double diffracted second measurement beam, in the first measurement direction back to the interferometer unit 20.

[0069] At the second semi-transparent mirror 22b, the double diffracted second measurement beam will be recombined with at least part of the second reference beam reflected on the second reference mirror 23b and guided towards the second detector 26. The second detector 26 provides a second interferometer signal on the basis of the received double diffracted second measurement beam and the second reference beam.

[0070] Thus, in the embodiment of Figure 5 two separate light sources are used to provide the first and second measurement beams and the first and second reference beams. Further, the first reflective target surface 11, the grating 12 and the second reflective target surface 13 are not formed by or

mounted on a wedge shaped reflection element but are separately mounted on the movable object 100, for example using a frame.

[0071] Other embodiments in which a non-45 degrees grating is used to reflect a first or higher order diffraction of a measurement beam in an angle of 90 degrees with respect to the direction of the measurement beam are also contemplated in order to create a bi-directional position measurement system are also contemplated. These position measurement systems may for example have gratings at an angle of more than 45 degrees with respect to the first reflective target surface and may have multiple light sources providing at least two radiation beams that can be distinguished by location or characteristics. In practice, multiple interferometer units 20 may be used in combination with one or more reflection elements 10 or similar constructions having a first reflective target surface 11, target 12 and second reflective target surface 13, and a single interferometer unit 20 may be combined with multiple reflection elements 10 or similar constructions having a first reflective target surface 11, target 12 and second reflective target surface 13.

[0072] Figure 6 shows a substrate positioning system comprising four movable substrate supports 100 and position measurement systems to measure the position of the substrate supports 100 in a first measurement direction, the x-direction, and a second measurement direction, the y-direction.

[0073] The position measurement system comprises a number of interferometer units 20 mounted on a reference object 200 and a number of reflection elements 10 mounted on the substrate supports 100. Each of the substrate supports 100 comprises four reflection elements 10. The interferometer units 20 and reflection elements 10 are embodied as shown in Figure 4.

[0074] The position measurement systems are arranged to determine the position of the substrate supports 100 in at least the x-direction and the y-direction using the bi-directional measurement set-up as proposed in this patent application.

[0075] Since the position measurement system is bi-directional, i.e. capable of measuring in two orthogonal measurement directions with measurement beams propagating between interferometer units 20 and reflection elements 10 in a single measurement direction, the interferometer units 20 are only arranged at two opposite sides of the area of movement 101 of the substrate support 100. There is no need to arrange interferometer units at the other two sides of the area of movement 101 extending in the x-direction. This is beneficial since the outer two substrate supports 100 may hinder the measurement beams propagating in the y-direction to reach the middle two substrate supports 100. As a further benefit, the sides without interferometers may be purposed for other functions such as substrate loading, without the need to enable interferometer control therefrom.

[0076] In the shown embodiment, interferometer units 20 are arranged at opposite sides of the area of movement 101. It is also possible to arrange the interferometer units 20 at only one side of the area of movement 101.

[0077] Each of the substrate supports 100 comprises four reflection elements 10, two at each side. In this embodiment, two reflection elements 10 at each side are used to have a lower maximum height

of the reflection elements 10 in the x-direction than when using only one reflection element 10 per side. The transition between the two reflection elements 10 is arranged at a different location in the y-direction for each side such that at least one of the interferometer units 20 is capable of measuring a position of the movable substrate support 100, when the other of the interferometer units 20 is aligned with a transition between the two reflection elements 20. In an alternative embodiment, the interferometer units 20 may be arranged in a staggered configuration to ensure that always one of the two opposed interferometer units 20 will be aligned with a reflection element 10.

[0078] According to embodiments of the invention, first or higher order diffractions of a measurement beam may be used. In this application, a first order diffraction may be a positive or negative first order diffraction. Correspondingly, a higher order diffraction may be a positive or negative higher order diffraction. Generally, if a positive n^{th}-order diffraction is used as the diffracted second measurement beam (where n=1, 2, 3, or higher), the double diffracted second measurement beam will be a negative n^{th}-order diffraction of the diffracted second measurement beam. Correspondingly, if a negative n^{th}-order diffraction is used as the diffracted second measurement beam (where n=1, 2, 3, or higher) the double diffracted second measurement beam will be a positive n^{th}-order diffraction of the diffracted second measurement beam.

[0079] Although specific reference may be made in this text to the use of a lithographic apparatus in the manufacture of ICs, it should be understood that the lithographic apparatus described herein may have other applications. Possible other applications include the manufacture of integrated optical systems, guidance and detection patterns for magnetic domain memories, flat-panel displays, liquid-crystal displays (LCDs), thin-film magnetic heads, etc.

[0080] Although specific reference may be made in this text to embodiments of the invention in the context of a lithographic apparatus, embodiments of the invention may be used in other apparatus. Embodiments of the invention may form part of a mask inspection apparatus, a metrology apparatus, or any apparatus that measures or processes an object such as a wafer (or other substrate) or mask (or other patterning device). These apparatus may be generally referred to as lithographic tools. Such a lithographic tool may use vacuum conditions or ambient (non-vacuum) conditions.

[0081] Although specific reference may have been made above to the use of embodiments of the invention in the context of optical lithography, it will be appreciated that the invention, where the context allows, is not limited to optical lithography and may be used in other applications, for example imprint lithography.

[0082] 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 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 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.

[0083] While specific embodiments of the invention have been described above, it will be appreciated that the invention may be practiced otherwise than as described. The descriptions above are intended to be illustrative, not limiting. Thus it will be apparent to one skilled in the art that modifications may be made to the invention as described without departing from the scope of the claims set out below. Other aspects of the invention are set out as in the following numbered clauses.

1. A position measurement system to measure a position of a movable object in at least a first measurement direction and a second measurement direction, wherein the first and second measurement directions are orthogonal to each other, comprising:

at least one light source to provide a first measurement beam and a second measurement beam,

interferometer optics to emit the first measurement beam and the second measurement beam in the first measurement direction,

a first reflective target surface perpendicular to the first measurement direction and arranged to reflect the first measurement beam,

a second reflective target surface perpendicular to the second measurement direction,

a grating positioned at a non-45 degree angle relative to the first reflective target surface and arranged to provide a diffracted second measurement beam in the second measurement direction using a first or higher order diffraction of the second measurement beam, wherein the grating is further arranged to provide a double diffracted second measurement beam in the first measurement direction using a first or higher order diffraction of the diffracted second measurement reflected on the second reflective surface,

at least one detector arranged to receive the first measurement beam reflected on the first reflective target surface and to receive the double diffracted second measurement beam.

2. The position measurement system of clause 1, wherein the diffracted second measurement beam is the first order diffraction of the second measurement beam and wherein the double diffracted second measurement beam is the first order diffraction of the diffracted second measurement beam.

3. The position measurement system of clause 1 or 2, wherein the at least one detector comprises a first detector to receive the first measurement beam reflected on the first reflective target surface and a second detector to receive the double diffracted second measurement beam.

4. The position measurement system of any of the clauses 1-3, wherein the at least one light source is arranged to provide a first reference beam and a second reference beam, wherein the first reference beam is guided via a first reference path to the at least one detector to interfere with the first measurement beam reflected on the first reflective target surface and wherein the second reference beam is guided via a second reference path to the at least one detector to interfere with the double diffracted second measurement beam.

5. The position measurement system of any of the clauses 1-4, wherein the position measurement system comprises a processing device to process the first measurement beam reflected on the first reflective surface and the double diffracted second measurement beam to determine a position of the movable object in the first measurement direction and the second measurement direction.

6. The position measurement system of any of the clauses 1-5, wherein the at least one light source is arranged to provide a single light beam comprising the first measurement beam and the second measurement beam, wherein the first measurement beam has a first polarization and the second measurement beam has a second polarization, wherein the first polarization and the second polarization are orthogonal to each other.

7. The position measurement system of clause 6, wherein the first reflective target surface is arranged to reflect light having the first polarization and to transmit light having the second polarization.

8. The position measurement system of any of the clauses 1-7, wherein the position measurement system comprises a wedge shaped reflection element transparent for the second measurement beam and having a right-angled triangular cross section, wherein a hypothenuse side of the right-angled triangular cross section supports or forms the grating and wherein one of the two other sides supports or forms the first reflective target surface, and the other of the two other sides supports or forms the second reflective target surface.

9. The position measurement system of clause 8, wherein a refractive index of a material of the wedge shaped reflection element is selected to increase the ratio between displacement of the movable object in the second measurement direction and a change in associated path length of the second measurement beam, diffracted measurement beam and double diffracted measurement beam in the wedge shaped reflection element.

10. The position measurement system of clause 8, wherein a refractive index of a material of the wedge shaped reflection element is selected to obtain a 1:1 ratio between displacement of the movable object in the second measurement direction and a change in associated path length of the second measurement beam, diffracted measurement beam and double diffracted measurement beam in the wedge shaped reflection element.

11. The position measurement system of any of the clauses 1-10, wherein the grating is a blazed angle grating.

12. The position measurement system of any of the clauses 1-11, wherein the position measurement system is arranged to measure the position of a movable object in at least the first measurement direction and the second measurement direction with respect to a reference object, wherein the at least one light source, the interferometer optics and the at least one detector are mounted on one of the movable object and the reference object and wherein the first reflective target surface, the second reflective target surface and the grating are mounted on the other of the movable object and the reference object.

13. The position measurement system of any of the clauses 1-12,
wherein the diffracted second measurement beam is a positive n^{th}-order diffraction of the second measurement beam and the double diffracted second measurement beam is a negative n^{th}-order diffraction of the diffracted second measurement beam, wherein n=1, 2, 3, or higher, or
wherein the diffracted second measurement beam is a negative n^{th}-order diffraction of the second measurement beam and the double diffracted second measurement beam is a positive n^{th}-order diffraction of the diffracted second measurement beam, wherein n=1, 2, 3, or higher.

14. The position measurement system of any of the clauses 1-13, wherein the first reflective target is arranged to transmit the second measurement beam.

15. A substrate positioning system comprising one or more movable substrate supports and one or more position measurement systems as described in any of the clauses 1-14 to measure the position of the one or more movable substrate supports in the first measurement direction and the second measurement direction.

16. A substrate positioning system comprising three or more movable substrate supports and three or more position measurement systems as described in any of the clauses 1-14 to measure the position of the one or more movable substrate supports in the first measurement direction and the second measurement direction.

17. A lithographic apparatus comprising the substrate positioning system of clause 15 or 16.

18. A method of measuring a position of a movable object in at least a first measurement direction and a second measurement direction, wherein the first and second measurement directions are orthogonal to each other, the method comprising:
providing a first measurement beam and a second measurement beam propagating in the first measurement direction,
reflecting the first measurement beam on a first reflective target surface arranged perpendicular to the first measurement direction,
using a grating positioned at a non-45 degree angle relative to the first reflective target surface and arranged to provide a diffracted second measurement beam in the second measurement direction using a first or higher order diffraction of the second measurement beam,
reflecting the diffracted second measurement beam on a second reflective target surface arranged perpendicular to the second measurement direction,

using the grating to provide a double diffracted second measurement beam in the first measurement direction using a first or higher order diffraction of the diffracted second measurement reflected on the second reflective surface, and

measuring the first measurement beam reflected on the first reflective surface and the double diffracted second measurement beam.

CLAIMS

1. A position measurement system to measure a position of a movable object in at least a first measurement direction and a second measurement direction, wherein the first and second measurement directions are orthogonal to each other, comprising:
at least one light source to provide a first measurement beam and a second measurement beam,
interferometer optics to emit the first measurement beam and the second measurement beam in the first measurement direction,
a first reflective target surface perpendicular to the first measurement direction and arranged to reflect the first measurement beam,
a second reflective target surface perpendicular to the second measurement direction,
a grating positioned at a non-45 degree angle relative to the first reflective target surface and arranged to provide a diffracted second measurement beam in the second measurement direction using a first or higher order diffraction of the second measurement beam, wherein the grating is further arranged to provide a double diffracted second measurement beam in the first measurement direction using a first or higher order diffraction of the diffracted second measurement reflected on the second reflective surface,
at least one detector arranged to receive the first measurement beam reflected on the first reflective target surface and to receive the double diffracted second measurement beam.

2. The position measurement system of claim 1, wherein the diffracted second measurement beam is the first order diffraction of the second measurement beam and wherein the double diffracted second measurement beam is the first order diffraction of the diffracted second measurement beam.

3. The position measurement system of claim 1 or 2, wherein the at least one detector comprises a first detector to receive the first measurement beam reflected on the first reflective target surface and a second detector to receive the double diffracted second measurement beam.

4. The position measurement system of any of the claims 1-3, wherein the at least one light source is arranged to provide a first reference beam and a second reference beam, wherein the first reference beam is guided via a first reference path to the at least one detector to interfere with the first measurement beam reflected on the first reflective target surface and wherein the second reference beam is guided via a second reference path to the at least one detector to interfere with the double diffracted second measurement beam.

5. The position measurement system of any of the claims 1-4, wherein the position measurement system comprises a processing device to process the first measurement beam reflected

on the first reflective surface and the double diffracted second measurement beam to determine a position of the movable object in the first measurement direction and the second measurement direction.

6. The position measurement system of any of the claims 1-5, wherein the at least one light source is arranged to provide a single light beam comprising the first measurement beam and the second measurement beam, wherein the first measurement beam has a first polarization and the second measurement beam has a second polarization, wherein the first polarization and the second polarization are orthogonal to each other.

7. The position measurement system of claim 6, wherein the first reflective target surface is arranged to reflect light having the first polarization and to transmit light having the second polarization.

8. The position measurement system of any of the claims 1-7, wherein the position measurement system comprises a wedge shaped reflection element transparent for the second measurement beam and having a right-angled triangular cross section, wherein a hypothenuse side of the right-angled triangular cross section supports or forms the grating and wherein one of the two other sides supports or forms the first reflective target surface, and the other of the two other sides supports or forms the second reflective target surface.

9. The position measurement system of claim 8, wherein a refractive index of a material of the wedge shaped reflection element is selected to increase the ratio between displacement of the movable object in the second measurement direction and a change in associated path length of the second measurement beam, diffracted measurement beam and double diffracted measurement beam in the wedge shaped reflection element.

10. The position measurement system of claim 8, wherein a refractive index of a material of the wedge shaped reflection element is selected to obtain a 1:1 ratio between displacement of the movable object in the second measurement direction and a change in associated path length of the second measurement beam, diffracted measurement beam and double diffracted measurement beam in the wedge shaped reflection element.

11. The position measurement system of any of the claims 1-10, wherein the position measurement system is arranged to measure the position of a movable object in at least the first measurement direction and the second measurement direction with respect to a reference object,

wherein the at least one light source, the interferometer optics and the at least one detector are mounted on one of the movable object and the reference object and wherein the first reflective target surface, the second reflective target surface and the grating are mounted on the other of the movable object and the reference object.

12. The position measurement system of any of the claims 1-11,
wherein the diffracted second measurement beam is a positive n^{th}-order diffraction of the second measurement beam and the double diffracted second measurement beam is a negative n^{th}-order diffraction of the diffracted second measurement beam, wherein n=1, 2, 3, or higher, or
wherein the diffracted second measurement beam is a negative n^{th}-order diffraction of the second measurement beam and the double diffracted second measurement beam is a positive n^{th}-order diffraction of the diffracted second measurement beam, wherein n=1, 2, 3, or higher.

13. A substrate positioning system comprising one or more movable substrate supports and one or more position measurement systems as claimed in any of the claims 1-12 to measure the position of the one or more movable substrate supports in the first measurement direction and the second measurement direction.

14. A lithographic apparatus comprising the substrate positioning system of claim 13.

15. A method of measuring a position of a movable object in at least a first measurement direction and a second measurement direction, wherein the first and second measurement directions are orthogonal to each other, the method comprising:
providing a first measurement beam and a second measurement beam propagating in the first measurement direction,
reflecting the first measurement beam on a first reflective target surface arranged perpendicular to the first measurement direction,
using a grating positioned at a non-45 degree angle relative to the first reflective target surface and arranged to provide a diffracted second measurement beam in the second measurement direction using a first or higher order diffraction of the second measurement beam,
reflecting the diffracted second measurement beam on a second reflective target surface arranged perpendicular to the second measurement direction,
using the grating to provide a double diffracted second measurement beam in the first measurement direction using a first or higher order diffraction of the diffracted second measurement reflected on the second reflective surface, and
measuring the first measurement beam reflected on the first reflective surface and the double diffracted second measurement beam.

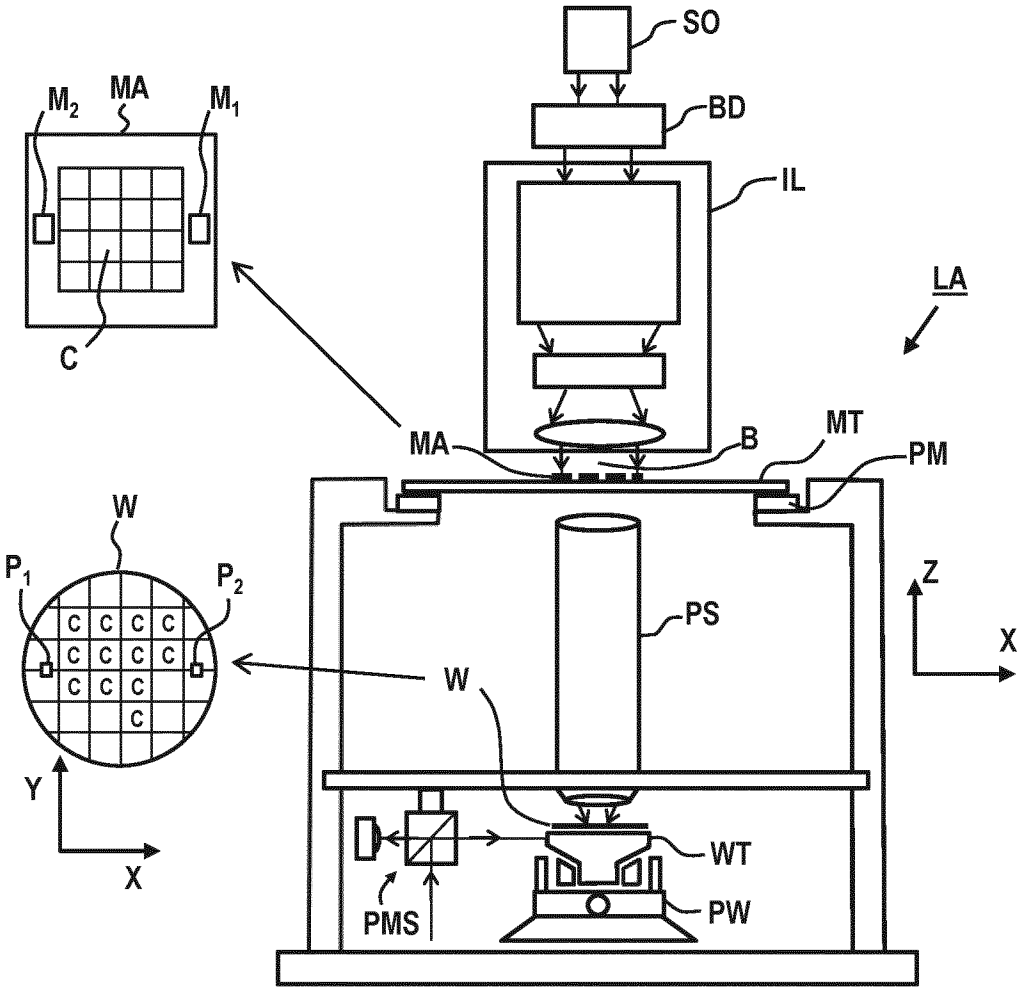

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Fig. 1

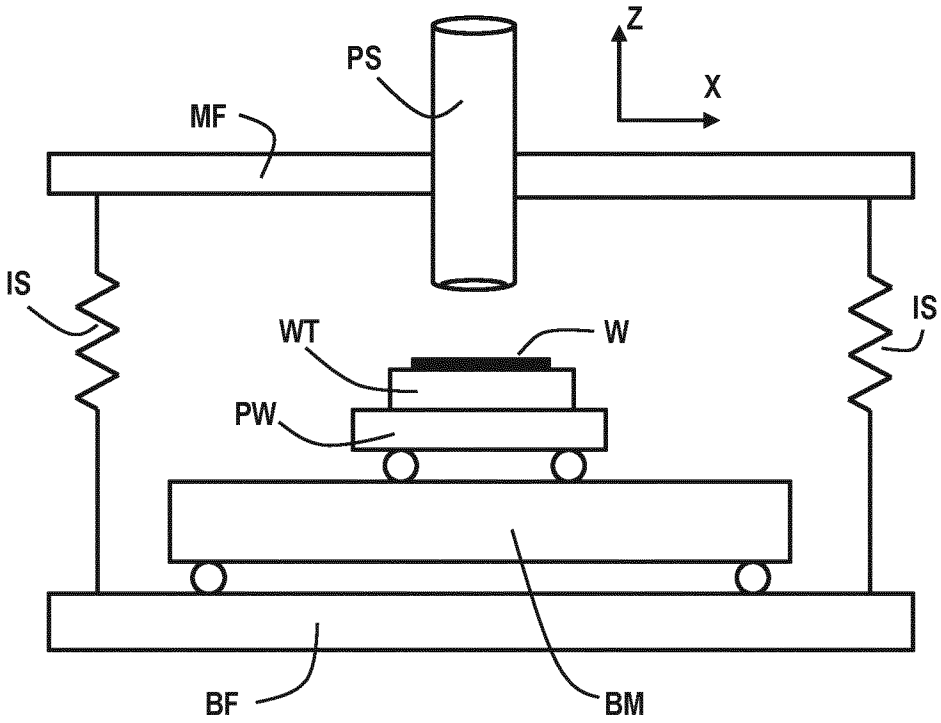


Fig. 2

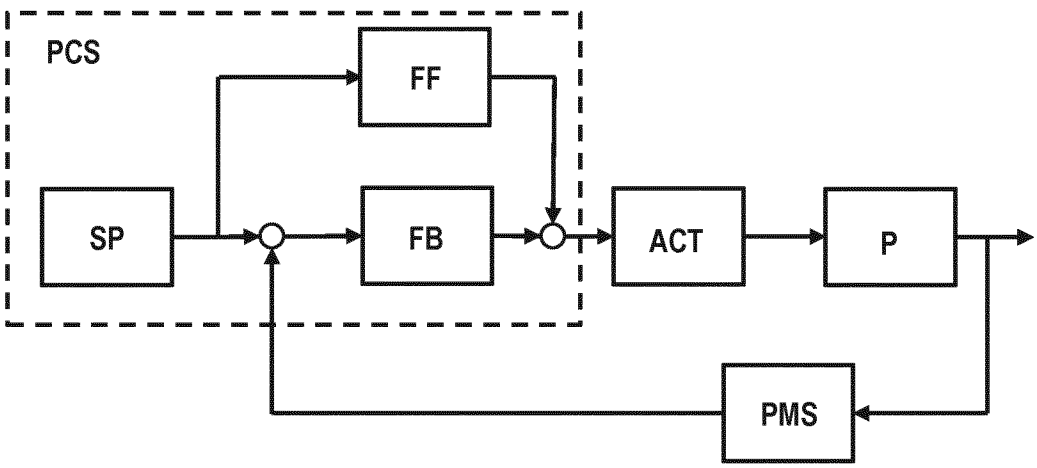


Fig. 3

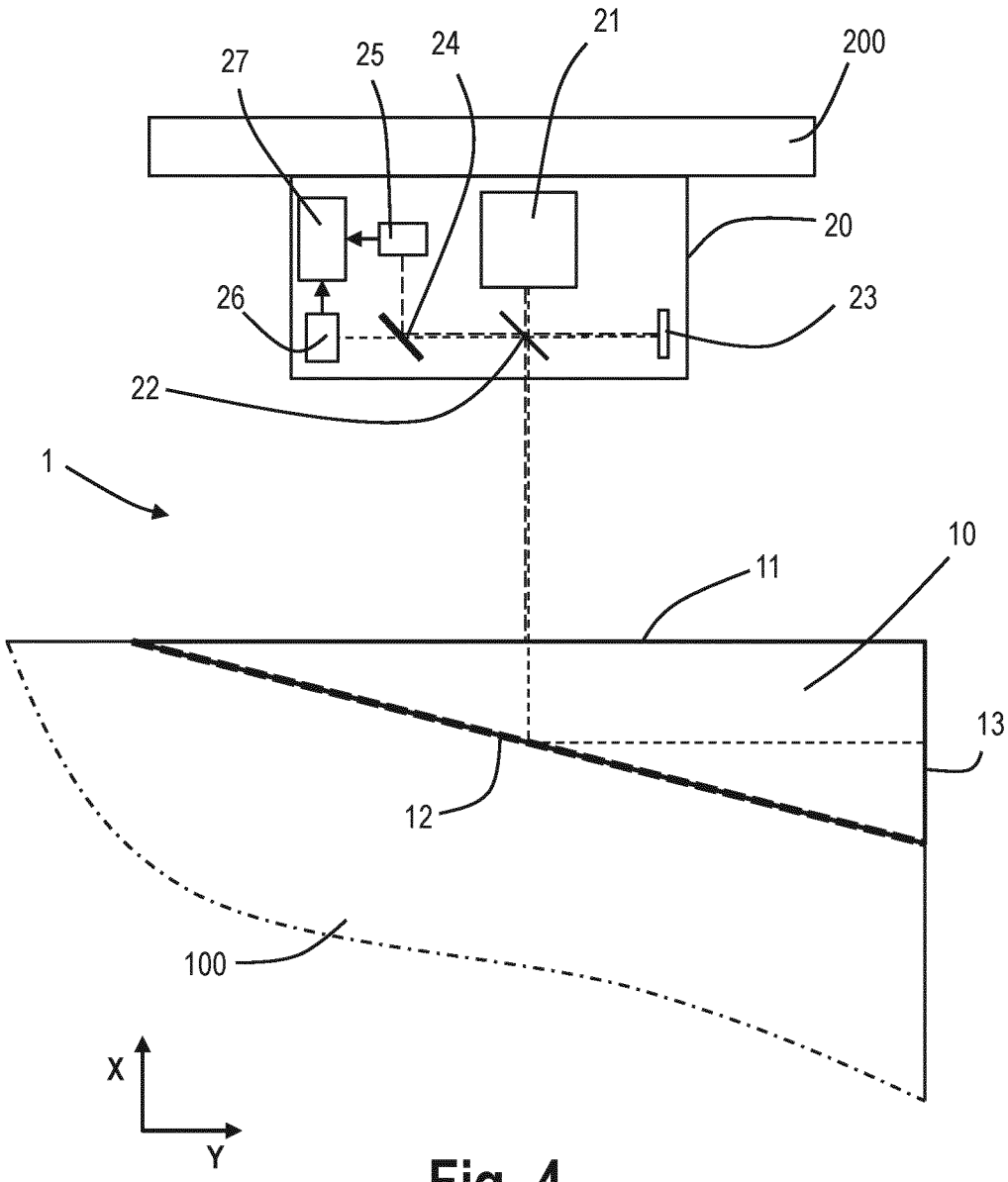


Fig. 4

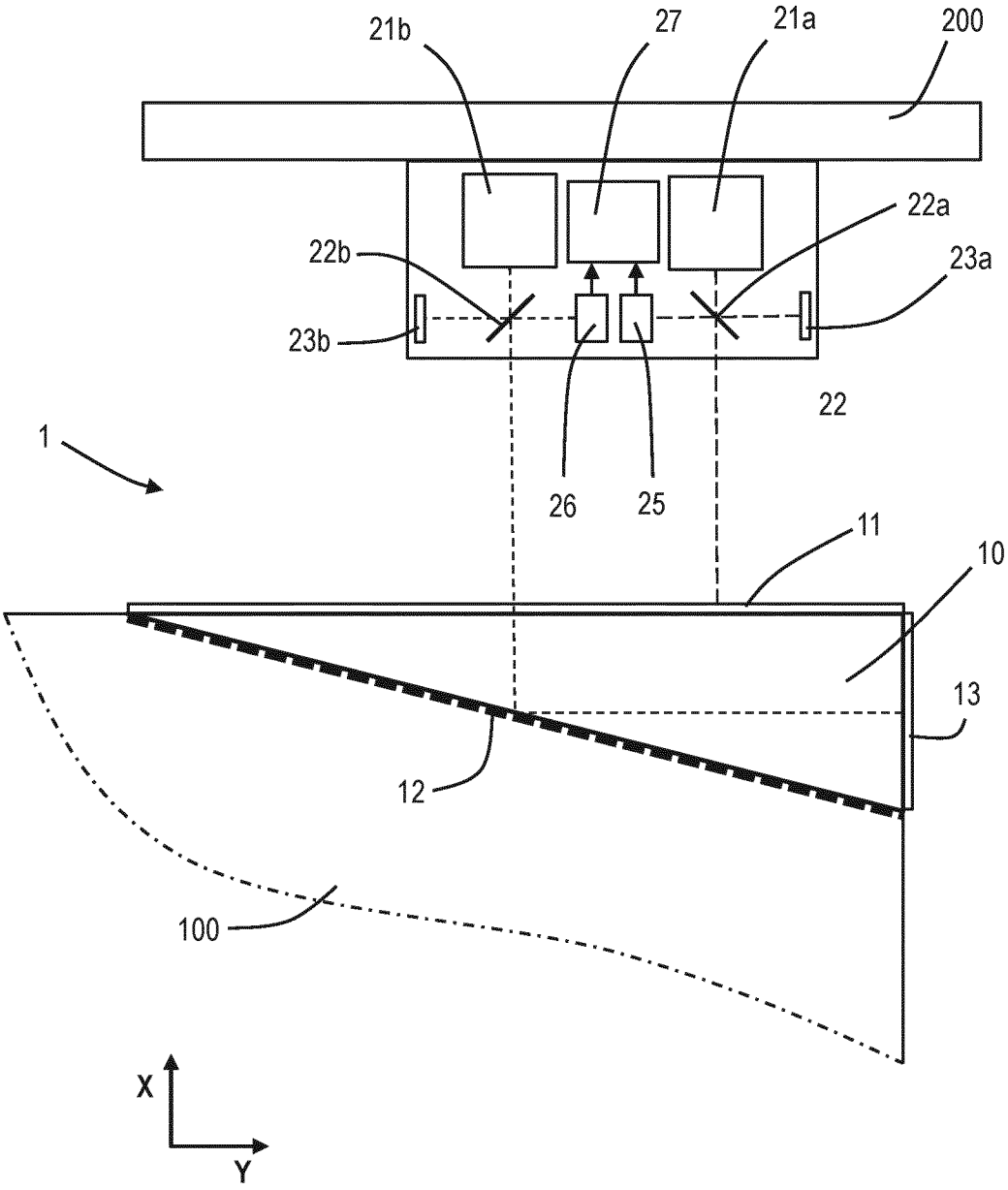


Fig. 5

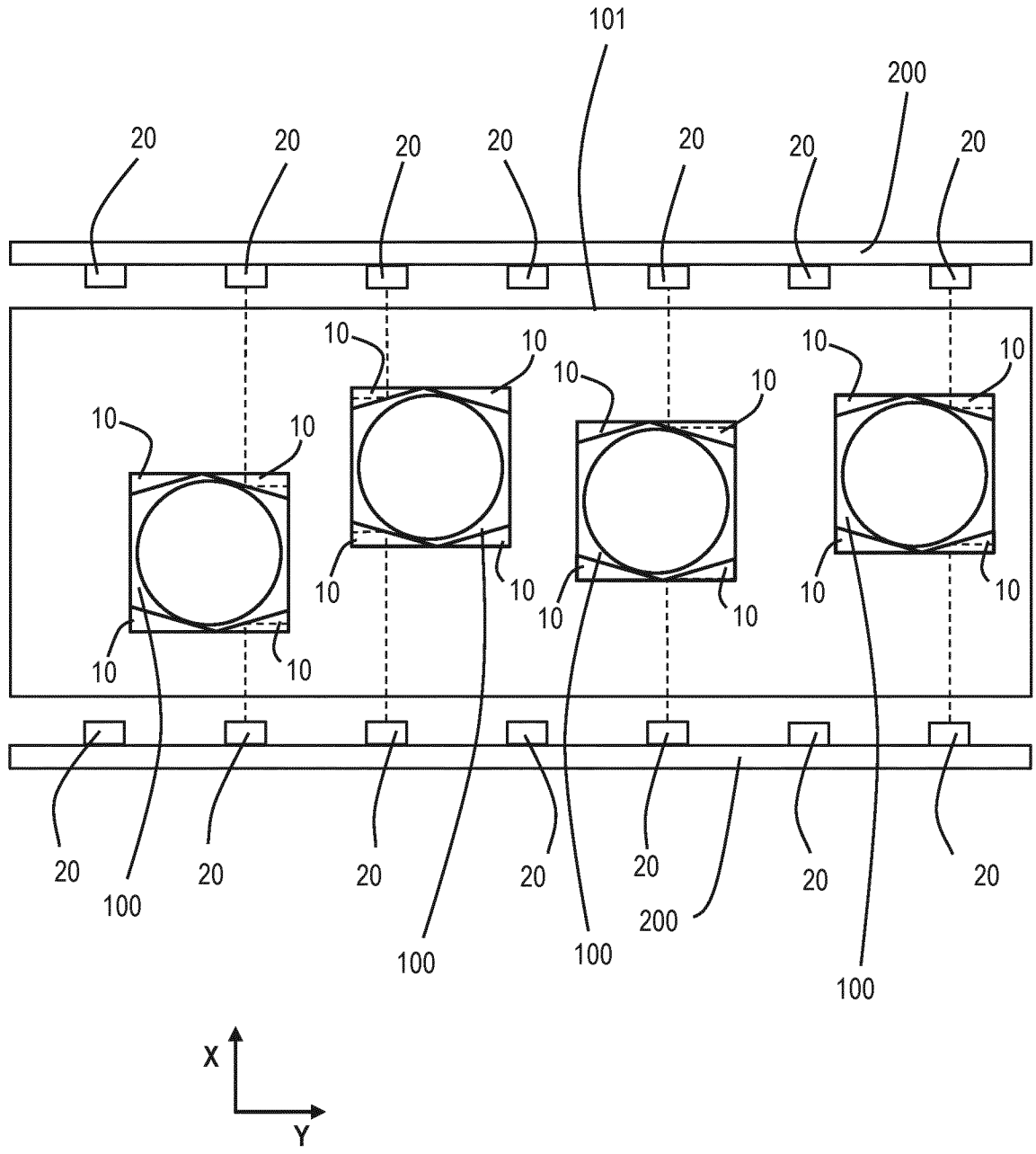


Fig. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2024/063259

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01B9/02015 G03F7/00
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)
G01B 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	WO 2023/280692 A1 (ASML NETHERLANDS BV [NL]) 12 January 2023 (2023-01-12) paragraphs [0002], [00034] - [00040]; figures 4,5	1-15
A	DE 10 2012 008745 A1 (ZEISS CARL SMS GMBH [DE]) 7 November 2013 (2013-11-07) paragraphs [0046] - [0067]; figures 1-7	1-15

☐ 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	Date of mailing of the international search report
26 June 2024	09/07/2024

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Biedermann, Benjamin

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2024/063259

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2023280692 A1	12-01-2023	CN 117546096 A	09-02-2024
		EP 4367557 A1	15-05-2024
		NL 2032345 A	16-01-2023
		WO 2023280692 A1	12-01-2023
DE 102012008745 A1	07-11-2013	DE 102012008745 A1	07-11-2013
		US 2013293962 A1	07-11-2013