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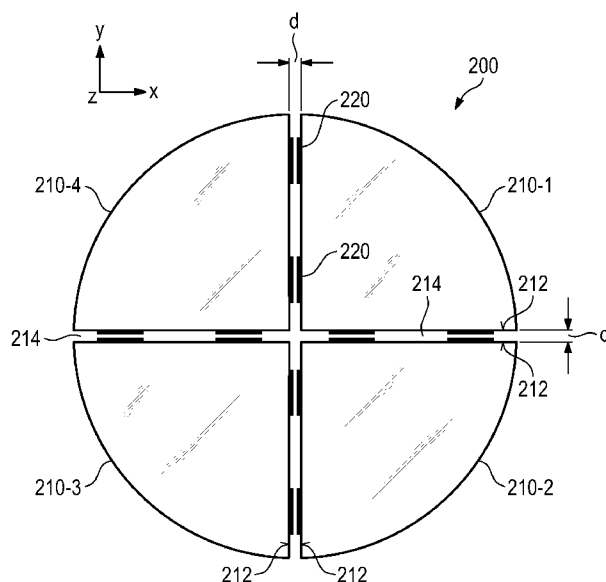


Fig. 2

(57) Abstract: A lithography apparatus (100) is disclosed, which comprises a mirror (200) having at least two mirror segments (210) which are joined together in such a way that an interspace (214) is formed between the mirror segments (210), and a sensor (220, 300) for detecting the relative position of the mirror segments (210), wherein the sensor (220, 300) is arranged in the interspace (214) between the mirror segments (210).

LITHOGRAPHY APPARATUS WITH SEGMENTED MIRROR

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims the priorities of the German patent application
5 DE 10 2012 212 064.5 (filed on July 11, 2012) and of the US patent application
US 61/670,215 (filed on July 11, 2012), the entire descriptions of which are
incorporated by reference herein.

FIELD OF THE INVENTION

10 The invention relates to a lithography apparatus comprising one or more
segmented mirrors.

RELATED ART

Lithography apparatuses are used for example in the production of integrated
15 circuits or ICs in order to image a mask pattern in a mask onto a substrate, such
as e.g. a silicon wafer. To this end, a light beam generated by an illumination
device is directed through the mask onto the substrate. An exposure lens
consisting of a plurality of optical elements serves for focusing the light beam on
the substrate. Examples of such lithography apparatuses are, in particular, EUV
20 (Extreme Ultra Violet) lithography apparatuses, which operate with optical
wavelengths for the exposure in the range of 4 nm to 30 nm. Such short
wavelengths make it possible to image extremely small structures on the wafer.
Since light in this wavelength range is absorbed by atmospheric gases, the beam
path of such EUV lithography apparatuses is situated in a high vacuum.
25 Furthermore, there is no material which is sufficiently transparent in the
wavelength range mentioned, for which reason mirrors are used as optical
elements for shaping and guiding the EUV radiation.

EUV lithography apparatuses having a large numerical aperture require mirrors
30 having a large diameter. Thus, diameters of 300 to 500 mm or more are required

for mirrors in proximity to the wafer. However, mirrors having such a large diameter are costly to produce. Furthermore, the availability of blanks or semi-finished parts for such sizes is encountering its limits. Moreover, with large mirror diameters, low-deformation mounting and actuation is also made more difficult. One possibility for combating this problem is to use segmented mirrors. In this case, a plurality of mirror segments are joined together to form a mirror. Consequently, the size of the mirror is no longer limited by the availability of blanks. Furthermore, low-deformation mounting of a plurality of individual mirror segments is also simpler than the low-deformation mounting of an integral mirror having a large diameter.

One difficulty which arises in this case, however, is that of precisely joining together the finished polished mirror segments. Since the different mirror segments together are intended to produce a single optical surface, the surface deviation, that is to say the difference in height between the mirror segments, should not be more than 20 nm, but this proves to be difficult. In this case, it is necessary to determine the positions of all the mirror segments with respect to all six degrees of freedom (three translational and three rotational), and if appropriate to readjust them by means of actuators. This means that, for example in the case of four mirror segments, a total of 24 sensors have to be provided, which entails a considerable outlay and space requirement.

The US patent application US 2011/0273694 A1 discloses a facet mirror composed of a multiplicity of individual mirrors, wherein the individual mirrors are individually drivable and have capacitive sensors for detecting their orientation.

It is therefore an object of the present invention to provide a lithography apparatus comprising a mirror arrangement with which at least one of the problems mentioned above is solved. In particular, it is an object of the present

invention to provide a lithography apparatus comprising a segmented mirror arrangement which enables space-saving and precise regulation of the positions of the mirror segments.

- 5 This object is achieved by means of a lithography apparatus, comprising a mirror having at least two (e.g. two to twelve) mirror segments which are joined together in such a way that an interspace is formed between the mirror segments, and a sensor for detecting the relative position of the mirror segments, wherein the sensor is arranged in the interspace.

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Arranging the sensor in the interspace between the mirror segments enables the relative positions of the mirror segments to be detected and regulated in a particularly space-saving manner. Consequently, it is no longer necessary to provide a plurality of sensors for each of the mirror segments outside the mirror.

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In order to detect the absolute position of the individual mirror segments, it suffices if the absolute position of a reference mirror segment is known, e.g. because the latter is detected by external sensors or because the latter is fixed relative to a reference point. The position of the other mirror segments can then be detected with the aid of sensors arranged between the mirror segments. Such a referencing makes it possible to detect so-called common-mode errors, that is to say positional errors that are common to all the mirror segments.

20

Furthermore, arranging the sensors in the interspace enables an in-situ measurement and thus a very precise measurement of the relative position of the mirror segments. The position of the individual mirror segments can be readjusted on the basis of the measurement results, wherein at the same time a calibration can be effected on the basis of an interferometric surface measurement of the mirror.

25

The mirror segments can each have at least one joining surface along which the mirror segments are joined together. Furthermore, a cutout can be provided in at least one of the joining surfaces, the sensor being arranged in said cutout. This makes it possible to design the distance between the mirror segments to be even
5 smaller, since the sensor can be arranged in a manner recessed in the cutout. By means of a small distance between the mirror segments, it is possible to achieve a virtually complete mirror surface having only small gaps, which improves the imaging properties of the mirror. In this case, "joining together" does not necessarily mean that the mirror segments are in contact with one another.

10 Rather, it is advantageous if the mirror segments are arranged in a manner free of contact with respect to one another. In this case, the joining surfaces are the surfaces of the mirror segments which are arranged opposite one another at a small distance from one another.

15 The sensor can be a capacitive sensor which generates a sensor signal dependent on the distance between the mirror segments. Such a capacitive sensor can be realized for example by metal electrodes situated opposite one another on the joining surfaces of the mirror segments. In this case, the metal electrodes can be embodied as thin metal layers, such that a small distance between the mirror
20 segments is made possible even without the sensor being recessed in the joining surface.

Furthermore, the sensor can also be embodied as an optical sensor. Optical sensors have a good drift behavior.

25

The optical sensor can be embodied as an optical encoder, in particular as an interference-based incremental encoder. A measurement accuracy into the picometers range can be achieved with such an encoder.

The lithography apparatus can furthermore comprise a sensor controller for driving the sensor and/or evaluating a sensor signal, wherein signals are transmitted wirelessly at least in sections between the sensor controller and the sensor. Thus, firstly a space saving is achieved, and secondly it is possible to
5 avoid vapors from cables for signal transmission which impair the vacuum.

The sensor can also be a pressure sensor which generates a sensor signal dependent on the pressure in the interspace, wherein the interspace is configured in such a way that a relative movement of the mirror segments brings about a
10 pressure change in the interspace. With such a pressure sensor, it is possible to achieve a good linearity of the sensor signal relative to changes in the position of the mirror segments.

The lithography apparatus can furthermore comprise a gas supply device for
15 supplying a gas into the interspace, and a gas extraction device for extracting the gas from the interspace. With such an arrangement, the gas is primarily or exclusively passed through the interspace, which enables a use under vacuum conditions, such as is necessary in particular for EUV lithography apparatuses.

20 The pressure sensor can comprise for example a tuning fork and an arrangement for detecting the resonant frequency of the tuning fork and/or the vibration amplitude at the resonant frequency. In this case, the tuning fork can have two vibrating elements which can be caused to vibrate by excitation, wherein the resonant frequency of the tuning fork and/or the vibration amplitude at the
25 resonant frequency are/is dependent on the pressure in the interspace. This is the case in particular when the width of the gap between the vibrating elements is smaller than the thickness of the vibrating elements by one or more orders of magnitude and the so-called squeeze effect occurs. Such a pressure sensor can be manufactured by microstructure engineering and can be designed to be
30 correspondingly flat. In this case, the vibrating elements can be manufactured

from structured semiconductor material or quartz. The pressure sensor can furthermore comprise electrodes which can be used to cause the vibrating elements to vibrate and which can be used to detect the resonant frequency of the tuning fork and/or the vibration amplitude at the resonant frequency.

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In the simplest embodiment, the interspace between the mirror segments is a gap, wherein the sensor is arranged in said gap. In this case, the joining surfaces do not have to be subjected to any special structuring for receiving the sensor. As an alternative thereto, the interspace can comprise a channel, in which the sensor is arranged. Such a channel can be formed by an, in particular rectangular, groove in at least one joining surface of one of the mirror segments. In this case, the groove can extend over the entire length of the joining surface. Such a groove can be produced comparatively simply by milling using a diamond milling unit or the like.

10

It is also possible for a plurality of sensors for detecting the relative position of the mirror segments with respect to a plurality of degrees of freedom to be provided in the interspace. In this case, the sensors provided in the interspace can detect the position of the mirror segments for example with respect to three translational and three rotational degrees of freedom.

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Furthermore, the lithography apparatus can comprise at least two actuators for separately actuating the individual mirror segments. Consequently, the position of the mirror segments can be regulated independently of one another.

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Further exemplary embodiments will be explained with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a schematic view of an EUV lithography apparatus in accordance with one embodiment;

Figure 2 is a schematic illustration of a mirror arrangement in accordance with one embodiment;

5 Figure 3 schematically shows two of the mirror segments in an exploded perspective illustration;

Figure 4 schematically shows the operative principle of a capacitive sensor;

Figures 5A and 5B show a cross section through the zy plane through one mirror segment;

10 Figure 6 shows a cross section through the zy plane through two adjacent mirror segments;

Figure 7 shows a perspective illustration of two mirror segments in accordance with a second exemplary embodiment;

15 Figure 8 shows a sectional illustration through a mirror segment and the arrangement of a pressure sensor in a sensor channel;

Figure 9 is a schematic illustration of an arrangement for introducing a gas into the sensor channel;

Figure 10 shows a cross-sectional view through the pressure sensor;

20 Figure 11 shows a plan view of the pressure sensor, wherein an upper cover plate of the pressure sensor has been removed for illustrative reasons.

Unless indicated otherwise, identical reference signs in the figures designate identical or functionally identical elements. Furthermore, it should be noted that the illustrations in the figures are not necessarily true to scale.

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EMBODIMENTS OF THE INVENTION

Figure 1 shows a schematic view of an EUV lithography apparatus 100 in accordance with one embodiment, which comprises a beam shaping system 102, an illumination system 104 and a projection system 106. The beam shaping
30 system 102, the illumination system 104 and the projection system 106 are in

each case provided in a vacuum housing which can be evacuated with the aid of an evacuation device (not illustrated in greater detail). The vacuum housings are surrounded by a machine room (not illustrated in greater detail) in which e.g. the drive devices for mechanically moving and/or adjusting the optical elements are provided. Furthermore, electrical controllers and the like can also be provided in said machine room.

The beam shaping system 102 comprises an EUV light source 108, a collimator 110 and a monochromator 112. As EUV light source 108, it is possible to provide a plasma source or a synchrotron, for example, which emit radiation in the EUV range (extreme ultraviolet range), that is to say e.g. in the wavelength range of 5 nm to 20 nm. The radiation emerging from the EUV light source 108 is firstly focused by the collimator 110, after which the desired operating wavelength is filtered out by the monochromator 112. Consequently, the beam shaping system 102 adapts the wavelength and the spatial distribution of the light emitted by the EUV light source 108. The EUV radiation 114 generated by the EUV light source 108 has a relatively low transmissivity through air, for which reason the beam shaping spaces in the beam shaping system 102, in the illumination system 104 and in the projection system 106 are evacuated.

In the example illustrated, the illumination system 104 comprises a first mirror 116 and a second mirror 118. These mirrors 116, 118 can be embodied for example as facet mirrors for pupil shaping and direct the EUV radiation 114 onto a photomask 120.

The photomask 120 is likewise embodied as a reflective optical element and can be arranged outside the systems 102, 104, 106. The photomask 120 has a structure which is imaged onto a wafer 122 or the like in a demagnified manner by means of the projection system 106. For this purpose, the projection system in the beam guiding space 106 comprises for example a third mirror 124 and a

fourth mirror 126. It should be noted that the number of mirrors of the EUV lithography apparatus 100 is not restricted to the number illustrated, and more or fewer mirrors can also be provided. Furthermore, the mirrors are generally curved at their front side for the purpose of beam shaping.

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Figure 2 is a schematic illustration of a mirror arrangement 200 in accordance with one embodiment, which corresponds for example to the mirror 126 in Figure 1. The mirror arrangement 200 comprises for example four mirror segments 210, namely the mirror segments 210-1, 210-2, 210-3 and 210-4. In plan view the mirror segments 210 each have the form of a quarter circle. The mirror segments 210 are joined together along their joining surfaces 212, such that together they produce a segmented mirror surface having a defined geometry. The reflective surface of the mirror segments 210 is curved, and in the example illustrated the mirror segments 210 together form a concave mirror for focusing an incident EUV light beam onto the wafer 122, cf. Figure 1. Generally, the arrangement described here can be applied to mirrors of all sizes. However, a segmentation of the mirror is particularly advantageous in the case of mirrors having large diameters, that is to say in the case of mirrors whose maximum diameter is e.g. greater than 30 cm or greater than 40 cm and is up to 100 cm or even more. Depending on the size of the mirror, the total height of the mirror arrangement can be 3 to 20 cm, for example. In the example illustrated, the mirror arrangement 200 is circular; however, said mirror arrangement is, of course, not restricted to this shape and can also be elliptical, oval, kidney-shaped or the like.

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The mirror segments 210-1, 210-2, 210-3 and 210-4 are mounted independently of one another and do not touch one another. Accordingly, they are actuated independently of one another by actuators (not illustrated in greater detail), as will be explained in greater detail below. Interspaces 214 are provided between the adjacent mirror segments 210-1, 210-2, 210-3 and 210-4. In one possible

30

variant, said interspaces 214 are formed by gaps, wherein said gaps have a gap width d.

Sensors 220 are arranged in the interspaces 214. Said sensors 220 measure the relative position of the mirror segments 210-1, 210-2, 210-3 and 210-4 with respect to one another. In this case, it is possible for the sensors 220 to detect the relative position of the mirror segments 210-1, 210-2, 210-3 and 210-4 with respect to one another with respect to all six degrees of freedom, that is to say with respect to their relative position on the three spatial axes x, y and z, and also their relative orientation with respect to rotations about the three spatial axes x, y and z. To put it more precisely, each of the sensors 220 generates a sensor signal containing information about the relative position of two of the mirror segments 210 with respect to one another with respect to at least one degree of freedom. If all six degrees of freedom are detected, then at least 18 sensors 220 are thus provided in the interspaces 214, e.g. six sensors 220 for detecting the relative position of the mirror segment 210-1 with respect to the mirror segment 210-2, six sensors 220 for detecting the relative position of the mirror segment 210-2 with respect to the mirror segment 210-3, and six sensors 220 for detecting the relative position of the mirror segment 210-3 with respect to the mirror segment 210-4. However, it is also possible that not all degrees of freedom are covered by the sensors 220 provided in the interspaces 214. By way of example, it is possible that the sensors 220 only detect the relative position of the mirror segments 210 with respect to the direction transversely with respect to the interspace 214, and the remaining parameters are detected by sensors arranged outside the mirror arrangement 200. In this case, therefore, the sensors 220 detect for example the relative position of the mirror segments 210-1 and 210-4 and also the relative position of the mirror segments 210-2 and 210-3 in the x-direction, and the relative position of the mirror segments 210-1 and 210-2 and also the relative position of the mirror segments 210-3 and 210-4 in the y-direction.

Furthermore, it is possible to provide outside the mirror arrangement 200 sensors which determine the position of at least one of the mirror segments 210 for all six degrees of freedom with respect to a measurement frame (not
5 illustrated in greater detail) provided in the lithography apparatus 100. Such a measurement frame can serve as a reference for the detection of the position of optical elements in the lithography apparatus, and is, in particular, positionally fixed relative to temperature changes, vibrations and the like. The position measurement for such a reference mirror segment 210 relative to the
10 measurement frame can be effected by means of laser interferometers, capacitive sensors or the like. If, by means of a position measurement for one of the mirror segments 210, for example for the mirror segment 210-1, the position of said mirror segment 210 with respect to the measurement frame is determined, then the position of each individual one of the remaining mirror segments 210, that is
15 to say of the mirror segments 210-2, 210-3 and 210-4, can also be deduced with the measurement values of the sensors 220.

The sensor signals generated by the sensors 220 are fed to an evaluation device (sensor controller or the like) (not illustrated in greater detail) which evaluates
20 the sensor signals. At least in sections, signals can in this case be transmitted wirelessly between the sensor and the evaluation device or sensor controller. By way of example, the signals can be transmitted as radio signals (electromagnetic waves) or as light signals. This has the advantage that the number of cables that are led through the vacuum region of the apparatus can be reduced. Thus, firstly
25 a space saving is achieved, and secondly it is possible to avoid vapors from such cables which impair the vacuum.

Depending on the evaluation result, the abovementioned actuators are driven in order to regulate the relative position of the mirror segments 210 to a specific
30 desired value. By way of example, the mirror segments 210 can be actuated such

that the maximum width d of the interspace 214 between the mirror segments 210 is not greater than 0.8 mm, preferably not greater than 0.4 mm or even not greater than 0.2 mm, and/or the surface deviation, that is to say the difference in height between the mirror segments 210, is not more than 20 nm, preferably not
5 more than 10 nm.

Since the mirror arrangement 200 of the lithography apparatus 100 is segmented into four mirror segments 210, the mirror arrangement 200 can be provided with a larger optical surface than a monolithic mirror arrangement 200. Furthermore,
10 the arrangement of the sensors 220 in the interspace 214 enables a space-saving detection and regulation of the positions of the mirror segments 210 with respect to one another.

Figure 3 schematically shows the mirror segments 210-1 and 210-2 in an
15 exploded perspective illustration. It should be noted that the surface of the mirror segments 210 is curved, and so the four mirror segments 210 together form a concave mirror. Correspondingly, the upper edge of the joining surface 212 is also curved, but this is not illustrated in the figures for the sake of simplicity. The lower edge of the joining surface 212 can be straight, or follow the course of
20 the curved upper edge, that is to say e.g. run parallel thereto. As illustrated in Figure 3, the mirror segments 210 each have a joining surface 212 at their straight sides, and the joining surfaces 212 of the mirror segments 210 are arranged opposite one another. The sensors 220 are arranged in or on the joining surfaces 212. In the example illustrated, four sensors 220 are arranged on the
25 mutually opposite joining surfaces 212 of the mirror segments 210-1 and 210-2, which sensors can be used to detect the relative position of the mirror segments 210-1 and 210-2 with respect to one or more degrees of freedom. In this case, the sensors can be embodied as surface sensors, which substantially respond to a change in the position of the mirror segments with respect to one degree of

freedom, or embodied as integrated sensors, which respond to a change in the position of the mirror segments with respect to a plurality of degrees of freedom.

As sensors 220, in principle it is possible to use all types of sensors which can be
5 used to detect displacements of the sensor segments 210 with respect to one another, in particular capacitive sensors. Optical sensors are generally possible as well; by way of example, a line pattern can be provided on a joining surface 212 and photosensors for detecting said line pattern can be provided on the opposite joining surface 212. However, in the case of such optical encoder sensors,
10 in general a certain evolution of heat occurs, which can influence the mirror geometry and can possibly necessitate cooling measures. The optical sensor can also be embodied as an interference-based incremental encoder. Such an encoder comprises an interferometer that is moved relative to a linear grating. In this case, a sinusoidal signal is generated e.g. from the optical reflections at a line
15 pattern or grating. By means of interpolation, it is possible to obtain a very high resolution which enables a measurement accuracy in the picometers range. The signal transmission between the encoder and the evaluation device or sensor controller can be effected wirelessly, as already mentioned above. Furthermore, it is possible for the cables for driving the sensor to be led toward the outside in
20 grooves provided in the mirror. For this purpose, the grooves explained in even greater detail below can also be used.

A first exemplary embodiment is described below, in which the sensors 220 are embodied as capacitive sensors. Figure 4 schematically shows the operative
25 principle of a capacitive sensor 220. Such a capacitive sensor 220 comprises measurement electrodes 222 and 224, which are arranged at the distance w from one another. The measurement electrodes 222 and 224 are connected to a capacitance measuring device 226, which generates a measurement signal X_m dependent on the capacitance of the measurement electrodes 222 and 224. The
30 capacitance of the measurement electrodes 222 and 224 is crucially dependent on

the distance between the measurement electrodes 222 and 224, which can be arranged on joining surfaces 212 situated opposite one another. Therefore, if the width d of the interspace changes and thus the distance between the measurement electrodes 222 and 224 also changes, then this can be detected by
5 the change in the electrically measurable capacitance by means of the measurement signal X_m . A shielding electrode 228 connected to a specific reference potential can optionally be arranged around the measurement electrode 222, said shielding electrode shielding the inhomogeneous marginal region of the electric field. As a result, an approximately parallel electric field arises between
10 the measurement electrodes 222 and 224. Consequently, even small changes in capacitance can be detected.

As already mentioned, the measurement electrodes 222 and 224 can each be arranged on opposite joining surfaces 212. The measurement electrodes 222 and
15 224 can be rectangular, for example, and can have a size of e.g. approximately 2 to approximately 15 mm by approximately 2 to approximately 15 mm. With one pair of measurement electrodes 222, 224 it is possible to detect the relative position of two mirror segments 210 with respect to one translational degree of freedom. Two pairs of measurement electrodes 222, 224 can be provided for
20 detecting the relative position of two mirror segments 210 with respect to one rotational degree of freedom.

The measurement electrodes 222, 224 can be produced from thin metal strips, e.g. composed of copper or the like. The lines connecting the measurement
25 electrodes 222, 224 to the capacitance measuring device 226 can be led along the joining surfaces 212. As an alternative thereto, they can also be led in grooves provided through the joining surfaces 212, or through the mirror segments 210. It is also correspondingly possible to arrange the measurement electrodes 222, 224 in cutouts provided in the joining surfaces 212. This is illustrated schematically
30 in Figures 5A and 5B, which each show a cross section through a mirror segment

210. In the variant illustrated in Figure 5A, an undercut is provided in the joining surface 212, the measurement electrode 222 or 224 being arranged in said undercut. In the variant illustrated in Figure 5B, a cutout is provided in the joining surface 212, the measurement electrode 222 or 224 being arranged in said cutout. Consequently, the measurement electrode 222 and 224, respectively, do not project into the gap between the joining surfaces 212, and so the mirror segments can be positioned even closer to one another. If the undercut or the cutout is provided along the entire joining surface 212, the lines for driving the measurement electrodes 222, 224 can also be provided therein.

On the basis of the measurement principle illustrated in Figure 4, changes in position with respect to the y-direction or rotations about the z- or y-axis can be detected with the sensor arrangements illustrated in Figure 3 and in Figures 5A and 5B. However, by means of corresponding configuration of the interspace 214 and arrangement of the measurement electrodes 222, 224 therein, it is possible also to detect changes in position with respect to other degrees of freedom. This is illustrated schematically in Figure 6, which shows a cross section through the zy plane through two adjacent mirror segments 210. In the case of the mirror segments 210 illustrated in Figure 6, the joining surfaces 212 have a substantially Z-shaped cross section in the region of the measurement electrodes 222, 224, such that an upper or lower part of the mirror segment 210 projects into the interspace 214. In this case, a section of the joining surfaces 212 respectively extends in the y-direction, that is to say in the direction transversely with respect to the interspace 214, and the measurement electrodes 222 and 224 are arranged on said sections. Consequently, in the case of a relative displacement of the mirror segments 210 in the z-direction, the capacitance provided by the measurement electrodes 222 and 224 changes, such that the relative position of the mirror segments 210 with respect to the z-direction can be detected. The mirror segments 210 illustrated in Figure 6 correspond to the

mirror segments 210-1 and 210-2 or to the mirror segments 210-3 and 210-4 in Figure 3.

The use of capacitive sensors as sensors 220 as explained above has the

5 advantage that the sensors 220 can be made very flat, that is to say require hardly any space in the interspace 214. Accordingly, the mirror segments 210 can be brought close together. Furthermore, capacitive sensors are well suited to use in a high vacuum, that is to say are suitable for vacuum. Furthermore, capacitive sensors can be driven from outside the evacuated region of the lithography
10 apparatus 100, such that no heat arises, or heat arises only slightly, in the evacuated region. However, they can represent a challenge insofar as the change in capacitance of the measurement electrodes 222, 224 is proportional to $1/w$ (inverse of the distance w between the measurement electrodes) and is therefore highly nonlinear particularly in the case of small gap widths. In this respect, the
15 provision of a specific minimum distance between the measurement electrodes 222 and 224 by recessing in the joining surfaces, as illustrated in Figures 5A and 5B, can be advantageous in order to achieve a more or less linear operating range.

20 In a lithography apparatus in accordance with a second exemplary embodiment, pressure sensors are used instead of the capacitive sensors described above. The general construction of the lithography apparatus of this second exemplary embodiment corresponds to the construction illustrated in Figure 1 and will therefore not be explained again. The pressure sensors used in the lithography
25 apparatus of the second exemplary embodiment will be explained with reference to Figures 7 to 11. In this case, elements which are identical or functionally identical to elements of the figures described above are identified by identical reference signs, and are not explained in greater detail. The same also applies to the following embodiments and figures.

Figure 7 shows a perspective illustration of two mirror segments 210-1 and 210-2 in accordance with a second exemplary embodiment. Figure 8 shows a sectional illustration through the mirror segment 210-1 and also the arrangement of a pressure sensor 300 in a sensor channel 240. Figure 9 is a schematic illustration of an arrangement for introducing a gas into the sensor channel 240.

As illustrated in Figures 7 to 9, in the adjacent mirror segments 210-1 and 210-2 of this embodiment, a groove 242 is respectively provided in the joining surface 212, which extends approximately centrally along the entire joining surface 212. Said groove 242 can be produced for example by milling using a diamond milling unit or the like. The two opposite grooves 242 together form a sensor channel 240. As viewed in cross section, therefore, the interspace 214 in this exemplary embodiment has the shape of a plus sign (+), with relatively narrow gaps at the top side and the underside of the mirror arrangement 200 and a widened sensor channel 240 therebetween.

The pressure sensor 300 is arranged in the sensor channel 240. To put it more precisely, the pressure sensor 300 can be arranged in one of the two opposite grooves 242. Furthermore, a gas supply device 250 and a gas extraction device 260 are respectively provided at the two ends of the sensor channel 240. The gas supply device 250 comprises a gas feeding tube 252, which is connected to a gas reservoir arranged outside the vacuum chamber, and also a gas nozzle 254. The gas extraction device 260 comprises a gas discharging tube 262, which is connected to the gas reservoir, and also a gas suction connector 264. By means of a pump (not illustrated in greater detail), a gas is pumped from the gas reservoir through the gas feeding tube 252 to the gas nozzle 254 and sprayed from the gas nozzle 254 with a predetermined pressure into the sensor channel 240. The gas is extracted from the sensor channel 240 via the gas suction connector 264 arranged at the opposite end of the sensor channel 240, and is led to the gas reservoir again via the gas discharging tube 262.

The gas used can be an inert gas, such as e.g. nitrogen or helium or the like. However, it is also possible to use air. It goes without saying that it is also possible to use a gas source connected to the gas feeding tube 252 and a gas sink
5 connected to the gas discharging tube 262, instead of just one gas reservoir.

The pressure in the sensor channel 240 is dependent firstly on the flow rate of the gas supplied and secondly on the cross-sectional area of the sensor channel 240. The cross-sectional area of the sensor channel 240 changes linearly with the
10 distance between the mirror segments 210. The pressure sensor 300 generates a sensor signal containing information about the gas pressure in the sensor channel 240. Since the flow rate of the gas is known, the distance between the mirror segments 210 can thus be deduced from said sensor signal. In other words, the pressure sensor 300 serves here as a position sensor that detects the
15 relative position of the mirror segments 210 with respect to the y-direction. By contrast, the pressure sensor 300 is not sensitive, or only very slightly sensitive, with respect to the relative position of the mirror segments 210 with respect to the x-direction and the z-direction, since changes in position in these directions do not lead to a change in the cross-sectional area of the sensor channel 240.

20 With the above-described arrangement in accordance with the second exemplary embodiment, the distance between the mirror segments 210 can be detected with the aid of a pressure sensor 300. In the case of this arrangement, the measurement variable, namely the pressure in the sensor channel 240, changes
25 substantially linearly with the relative position to be detected of the mirror segments 210 in the y-direction. Consequently, it is possible to achieve a good linearity of the measurement signal over a larger measurement range than with capacitive sensors, for example.

The relative position of the mirror segments 210 in the y-direction can be detected with the arrangement described above. However, by means of corresponding configuration of the sensor channel, it is possible also to detect the relative position of the mirror segments 210 with respect to other degrees of freedom. Thus, by way of example, the interspace 214 between the mirror segments 210 can be configured as illustrated in Figure 6, and, instead of the measurement electrodes 222 and 224, a pressure sensor 300 can be arranged in the central region between the mirror segments 210, which in this case serves as a sensor channel. A change in the relative position of the mirror segments 210 in the z-direction thus leads to a change in the cross-sectional area of the sensor channel, such that the pressure in the sensor channel changes. Such an arrangement thus makes it possible to detect the relative position of the mirror segments 210 in the z-direction.

By means of a corresponding configuration of the sensor channel and arrangement of a corresponding number of pressure sensors, it is thus possible to detect the relative position of the mirror segments 210 with respect to all six degrees of freedom.

In this case, it is also possible to provide a plurality of channels per segment pair, wherein at least one pressure sensor is arranged in each channel, and the individual sensors respond to positional displacements of the mirror segments 210 in different spatial directions.

In one alternative configuration, it is also possible for just one gas inlet to be arranged in the center of the mirror, which conducts the gas into the various channels arranged in a star-shaped manner. In this case, the gas is conducted along the channels toward the outside and taken up there by the gas suction connectors.

In accordance with the second embodiment described above, exactly one pressure sensor 300 is arranged in the sensor channel 240. However, it is also possible to arrange a plurality (e.g. two or four or more) of pressure sensors 300 along the sensor channel 240. A more precise measurement value can thus be determined
5 by averaging the sensor signals generated. Furthermore, it is also possible, by means of a corresponding evaluation, to detect rotations about the z-axis or the like with such an arrangement.

Furthermore, it is not necessary to provide the grooves 242 at both opposite
10 joining surfaces 212, and it suffices to provide one sensor channel 240, through which gas flows and in which the pressure sensor 300 is arranged.

A so-called “leaky seal” can be used as sealing for the interspace. In this case, the free path length of the gas admitted into the channel is chosen with respect to the
15 narrowest gap of the joint such that the gas cannot emerge, or can emerge only to a very small extent, through this narrow gap.

The pressure sensor 300 has to be small enough to be able to be arranged in the interspace 214 or in the sensor channel 240. One possible embodiment of such a
20 pressure sensor 300 is illustrated below with reference to Figures 10 and 11.

Figure 10 shows a cross-sectional view through the pressure sensor 300. Figure 11 shows a plan view of the pressure sensor 300, wherein an upper cover plate of the pressure sensor 300 has been removed for illustrative reasons.

25 The pressure sensor 300 has a four-layered construction and comprises, from the bottom to the top, a lower cover plate 310, a lower chip plane 320, an upper chip plane 330 and an upper cover plate 340. The cover plates 310 and 340 can be produced from glass or from silicon, for example, and serve as carrier elements for the chip planes 320 and 330 arranged therebetween.

The chip planes 320 and 330 are in each case produced monolithically from silicon or a comparable semiconductor material, or else from quartz or the like. The chip planes 320 and 330 in each case have a circumferential chip frame 321 and 331, respectively, a first spring element 322 and 332, respectively, a base element 323 and 333, respectively, a second spring element 324 and 334, respectively, and a vibrating element 325 and 335, respectively. The chip planes 320 and 330 will be explained by way of example on the basis of the chip plane 330. The construction of the chip plane 320 corresponds to that of the chip plane 330. Figure 11 shows a plan view of the chip plane 330, that is to say shows the pressure sensor 300 with the cover plate 310 removed. As shown in Figure 11, the chip frame 331 has the form of a circumferential rectangular frame and is fixed to the underside of the upper cover plate 340.

The first spring element 332 extends from a shorter side of the chip frame 331, said spring element having a smaller height than the chip frame 331. The base element 333 is adjacent to the first spring element 332, said base element being connected to the vibrating element 335 by means of the second spring element 334. The second spring element 334, too, has a smaller height than the chip frame 331, the base element 333 and the vibrating element 335. A thermal oxide 305 is provided between the chip frames 321 and 331, the first springs 322 and 332, and the base elements 323 and 333, said thermal oxide serving as insulation between the two chip planes 320 and 330.

The first spring elements 322 and 332 serve as vibrating springs which only allow vibrations in the z-direction. They therefore serve for the vibration decoupling of the base elements 323 and 333 relative to the chip frames 321, 331. This makes the pressure sensor 300 less sensitive to external vibrations and the like. The vibrating elements 325 and 335 are in turn fixed to the base elements 323 and 333 in a freely vibrating manner by means of the second spring elements 324, 334. The vibrating elements 325 and 335 together with the second spring

elements 324, 334 and the base elements 323 and 333 form a tuning fork 350. A vibration gap 352 is formed between the vibrating elements 325 and 335 of the tuning fork 350, the width of which can be 2 to 3 micrometers, for example.

5 On the inner sides of the cover plates 310, 340, provision is made of first electrodes 311 and 341, respectively, wherein said first electrodes 311 and 341, respectively, are arranged opposite the vibrating elements 325 and 335, respectively. The electrodes 311 and 341, respectively, are connected to a sensor controller (not illustrated in greater detail) via plated-through holes 312 and 342,
10 provided in the cover plates 310 and 340, via conduction elements 313 and 343 on the outer side of the cover plates 310 and 340. Second electrodes 326 and 336 are provided on those sides of the vibrating elements 325 and 335 which face the cover plates 310, 340, which second electrodes can be connected to a predetermined potential. The electrodes 311, 326, 336, 341 can be produced from
15 a thin metal layer, e.g. composed of aluminum. The first electrodes 311 and 341, respectively, serve two purposes, namely the excitation of vibrations of the vibrating elements 325 and 335 and the detection of the vibration state thereof.

The cover plates 310 and 340 together with the chip frames 321 and 331 form a
20 housing, in the interior of which the tuning fork 350 is arranged. The interior of said housing is connected to the environment of the pressure sensor 300 via through-holes 314 and 344, with the result that substantially the same pressure prevails within and outside the housing.

25 The sensor principle of the pressure sensor 300 is outlined below. By means of a suitable AC voltage being applied to the first electrodes 311 and 341, the tuning fork 350 is excited to effect continuous vibrations having a constant amplitude (of e.g. a few nm) at its mechanical natural frequency. In this case, the vibrating elements 325 and 335 move in opposite directions along the z-axis. The vibration
30 gap 352 therefore becomes periodically wider and narrower. When the vibrating

elements 325 and 335 move toward one another, part of the gas escapes from the vibration gap 352 and produces friction losses. That part of the gas which remains in the vibration gap 352 is compressed and acts as an additional spring (so-called “squeeze effect”). Both the friction losses and the spring effect on
5 account of the gas have a great dependence on pressure, in particular also at low pressures as far as the vacuum range, and so the arrangement described is suitable as a pressure sensor. The natural frequency of the tuning fork 350 and the pressure dependence of the damping can be set by means of a suitable dimensioning of the vibrating elements 325, 335 and of the spring elements 324
10 and 334.

The drive force which is required for the excitation of the tuning fork 350 and which corresponds to the amplitude of the drive voltage is proportional to the damping of the vibration of the tuning fork 350. In pressure ranges in which the
15 damping depends predominantly on the ambient pressure, the amplitude of the drive voltage is thus a sensitive measure of the pressure. The first electrodes 311, 341 for exciting the tuning fork 350, together with a suitable evaluation circuit, can thus be used as an arrangement for detecting the pressure-dependent resonant frequency of the tuning fork 350 and/or the vibration amplitude at the
20 resonant frequency. The pressure in the region of the sensor 300, and thus the distance between the mirror segments 210 can then be deduced from the detected resonant frequency and/or vibration amplitude.

Pressure sensors similar to those described above can also be found in the
25 German patent application DE 100 33 182 A1 and in the postdoctoral thesis “Technologieentwicklung für kapazitive Sensoren mit bewegten Komponenten” [“Technological development for capacitive sensors with moving components”], Dr.-Ing. Karla Hiller, TU Chemnitz, 2004, in particular Chapter 4 therein. With regard to further technical details, therefore, reference is made to these
30 documents.

The pressure sensor 300 described here is very sensitive even at low pressures, with the result that it suffices to admit a comparatively small amount of gas into the sensor channel 240 and extract it. It can thus be ensured that no, or only a slight amount of gas escapes into the vacuum region in which the mirror arrangement 200 is arranged. Furthermore, the pressure sensor 300 can be made very flat, with a total height of approximately 300 to 400 μm . This makes it possible to design the sensor channel 240 to be very narrow, such that even slight changes in the width of the interspace 214 lead to comparatively large pressure changes in the sensor channel 240. Consequently, a high sensor sensitivity can be achieved. It is also conceivable for the interspace 214 not to have a sensor channel 240, and for the pressure sensors 300 to be provided areally on the joining surfaces 212, cf. Figure 2.

The sensor signals generated by the sensors 220 and 300 can be fed to a control device (not illustrated in greater detail). On the basis of the sensor signals, the control device determines actuator signals which are fed to the abovementioned actuators and which guide the individual mirror segments 210 in each case into their desired position and orientation in which the mirror segments 210 lie flush alongside one another and the surface deviation is minimal, that is to say for example not greater than 20 nm. In this case, the individual mirror segments 210 can be actuated independently of one another, to be precise with respect to all six degrees of freedom. In the case of four mirror segments 210, therefore, 24 actuators can be provided, for example. The exemplary embodiments described above therefore provide regulating arrangements for regulating the relative position of the mirror segments 210 with respect to all degrees of freedom. In this case, the mirror segments 210 can initially be adjusted upon the start-up of the lithography apparatus 100 or else be readjusted during operation by a control loop.

The actuators can be embodied for example as Lorentz actuators or else as piezo actuators.

It should be noted that the embodiments described above are merely by way of
5 example and can be varied in diverse ways in the context of the scope of protection of the patent claims. In particular, the features of the embodiments described above can also be combined with one another.

Furthermore, various configurations for mirror arrangements have been
10 explained on the basis of the mirror arrangement 200 of the lithography apparatus 100. However, the configurations illustrated can, of course, also be applied to any other mirror of the lithography apparatus 100.

Furthermore, exemplary embodiments of a mirror arrangement in an EUV
15 lithography apparatus have been explained. However, the invention is not restricted to EUV lithography apparatuses, but rather can also be applied to other lithography apparatuses.

Furthermore, the mirror arrangement is not restricted to four mirror segments,
20 and it is also possible to provide fewer than four (that is to say two or three mirror segments) or more than four mirror segments.

LIST OF REFERENCE SIGNS

25	100	EUV lithography apparatus
	102	Beam shaping system
	104	Illumination system
	106	Projection system
	108	EUV light source
30	110	Collimator

	112	Monochromator
	114	EUV radiation
	116	First mirror
	118	Second mirror
5	120	Photomask
	122	Wafer
	124	Third mirror
	126	Fourth mirror
	200	Mirror arrangement
10	210-1 ... 210-4	Mirror segments
	212	Joining surfaces
	214	Interspace
	220	Sensors
	222, 224	Measurement electrodes
15	226	Capacitance measuring device
	228	Shielding electrode
	240	Sensor channel
	242	Groove
	250	Gas supply device
20	252	Gas feeding tube
	254	Gas nozzle
	260	Gas extraction device
	262	Gas discharging tube
	264	Gas suction connector
25	300	Pressure sensor
	305	Thermal oxide
	310	Lower cover plate
	311, 341	First electrodes
	312, 342	Plated-through holes
30	313, 343	Conduction elements

	320	Lower chip plane
	321, 331	Chip frames
	322, 332	First spring elements
	323, 333	Base elements
5	324, 334	Second spring elements
	325, 335	Vibrating elements
	326, 336	Second electrodes
	330	Upper chip plane
	340	Upper cover plate
10	350	Tuning fork
	352	Vibration gap

PATENT CLAIMS

1. Lithography apparatus (100), comprising:

a mirror (200) having at least two mirror segments (210) which are joined
5 together in such a way that an interspace (214) is formed between the mirror
segments (210); and

a sensor (220, 300) for detecting the relative position of the mirror
segments (210),

wherein the sensor (220, 300) is arranged in the interspace (214) between
10 the mirror segments (210).

2. Lithography apparatus (100) according to Claim 1, wherein the mirror
segments (210) each have at least one joining surface (212) along which the
mirror segments (210) are joined together, and a cutout is provided in at least
15 one of the joining surfaces (212), the sensor (220, 300) being arranged in said
cutout.

3. Lithography apparatus (100) according to Claim 1 or 2, wherein the sensor
(220, 300) is a capacitive sensor or an optical sensor which generates a sensor
20 signal dependent on the distance between the mirror segments (210).

4. Lithography apparatus (100) according to Claim 3, wherein the optical sensor
is embodied as an optical encoder, in particular as an interference-based
incremental encoder.

5. Lithography apparatus (100) according to any of Claims 1 to 4, furthermore
comprising a sensor controller for driving the sensor and/or evaluating a sensor
signal, wherein signals are transmitted wirelessly at least in sections between
the sensor controller and the sensor.

6. Lithography apparatus (100) according to any of Claims 1 to 5, wherein the interspace (214) is configured in such a way that a relative movement of the mirror segments (210) brings about a pressure change in the interspace (214), and the sensor (220, 300) is a pressure sensor which generates a sensor signal
5 dependent on the pressure in the interspace (214).

7. Lithography apparatus (100) according to Claim 6, furthermore comprising:
a gas supply device (250) for supplying a gas into the interspace (214); and
a gas extraction device (260) for extracting the gas from the interspace
10 (214).

8. Lithography apparatus (100) according to Claim 6 or 7, wherein the pressure sensor (300) comprises the following:

a tuning fork (350) having two vibrating elements (325, 335), which can be
15 caused to vibrate by excitation, wherein the resonant frequency of the tuning fork (350) and/or the vibration amplitude at the resonant frequency depend(s) on the pressure in the interspace (214), and

an arrangement for detecting the resonant frequency of the tuning fork (350) and/or the vibration amplitude at the resonant frequency.
20

9. Lithography apparatus (100) according to Claim 8, wherein the vibrating elements (325, 335) are made of structured semiconductor material or quartz.

10. Lithography apparatus (100) according to Claim 8 or 9, wherein the pressure
25 sensor (300) furthermore comprises electrodes (311, 341) which can be used to cause the vibrating elements (325, 335) to vibrate and which can be used to detect the resonant frequency of the tuning fork (350) and/or the vibration amplitude at the resonant frequency.

11. Lithography apparatus (100) according to any of the preceding claims,
wherein the interspace (214) is a gap between the mirror segments (210).

12. Lithography apparatus (100) according to any of the preceding claims,
5 wherein the interspace (214) comprises a channel (240), in which the sensor (220,
300) is arranged.

13. Lithography apparatus (100) according to Claim 11, wherein the channel
(240) is formed by an, in particular rectangular, groove (242) in at least one
10 joining surface (212) of one of the mirror segments (210).

14. Lithography apparatus (100) according to Claim 13, wherein the groove (242)
extends along the entire length of the joining surface (212).

15 15. Lithography apparatus (100) according to any of the preceding claims,
wherein the sensor (220, 300) is suitable for vacuum.

16. Lithography apparatus (100) according to any of the preceding claims,
wherein a plurality of sensors (220, 300) for detecting the relative position of the
20 mirror segments (210) with respect to a plurality of degrees of freedom are
provided in the interspace (214).

17. Lithography apparatus (100) according to Claim 16, wherein the sensors (220,
300) provided in the interspace (214) detect the position of the mirror segments
25 (210) with respect to three translational and three rotational degrees of freedom.

18. Lithography apparatus (100) according to any of the preceding claims,
furthermore comprising at least two actuators for separately actuating the
individual mirror segments (210).

19. Lithography apparatus (100) according to any of the preceding claims, wherein the mirror segments (210) are arranged in a manner free of contact with respect to one another.

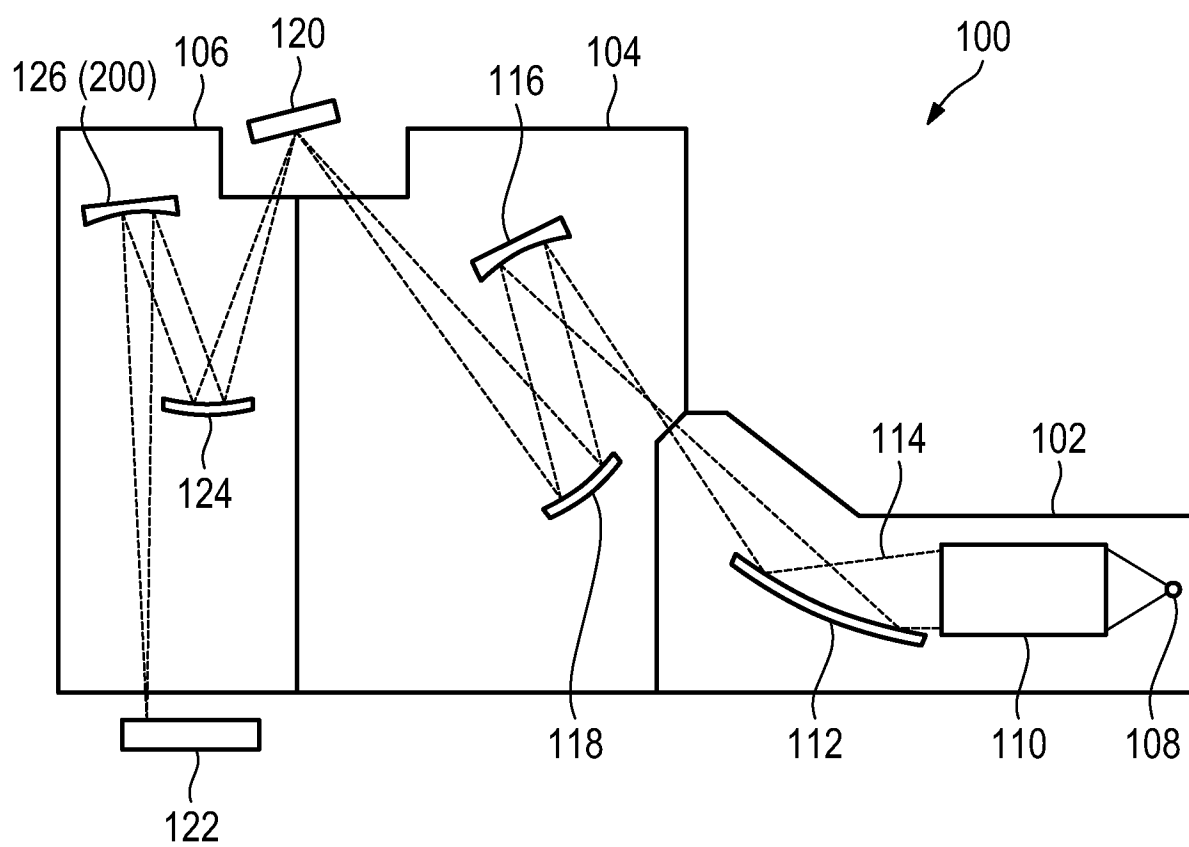
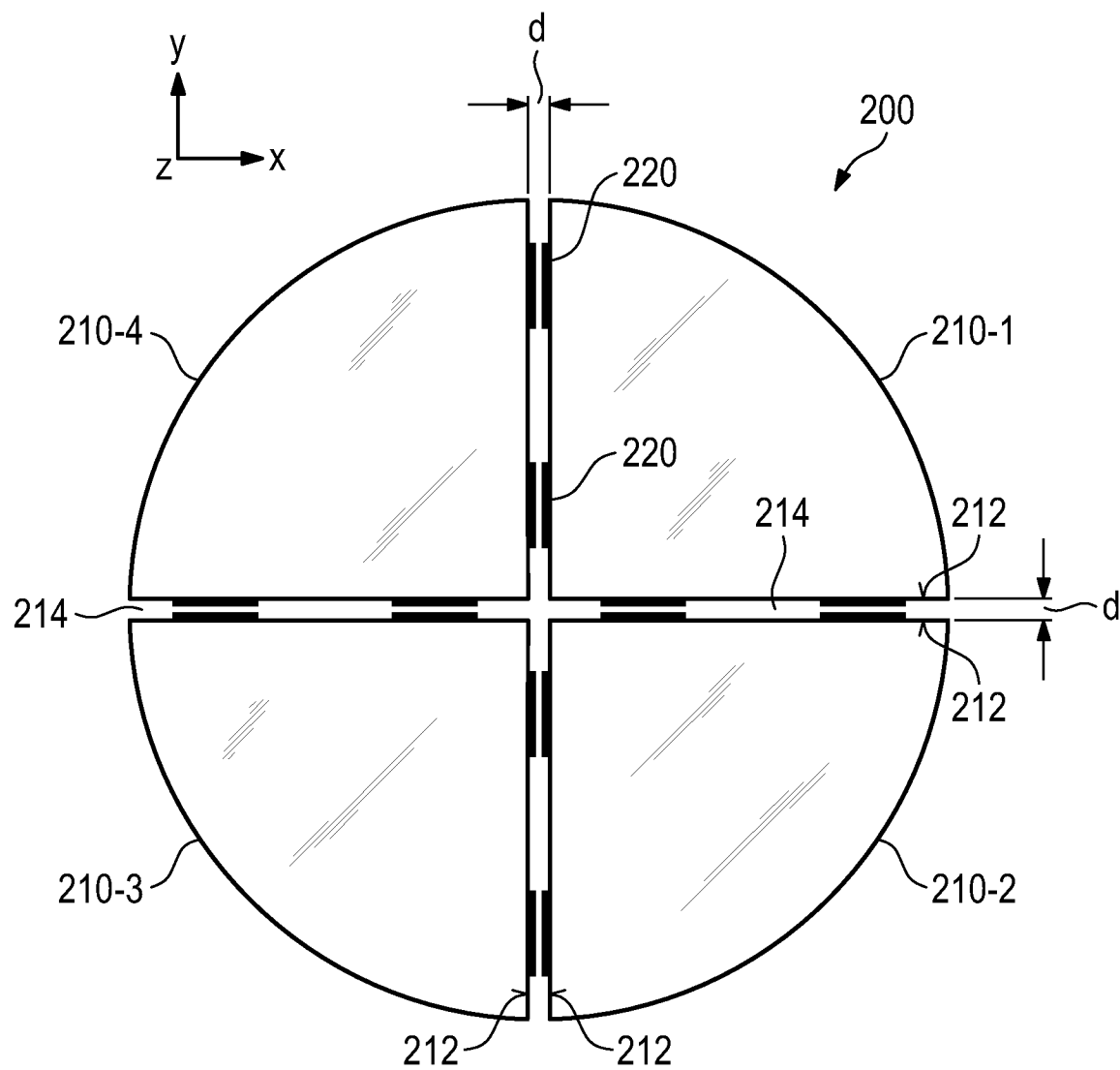


Fig. 1

**Fig. 2**

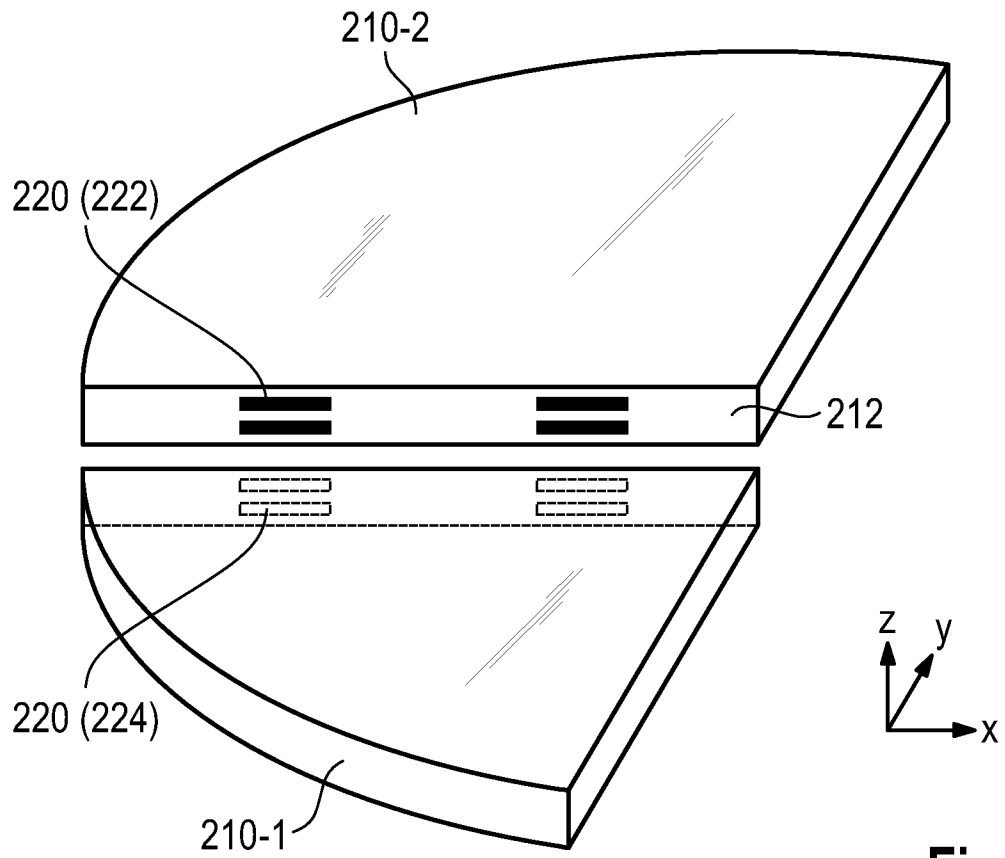


Fig. 3

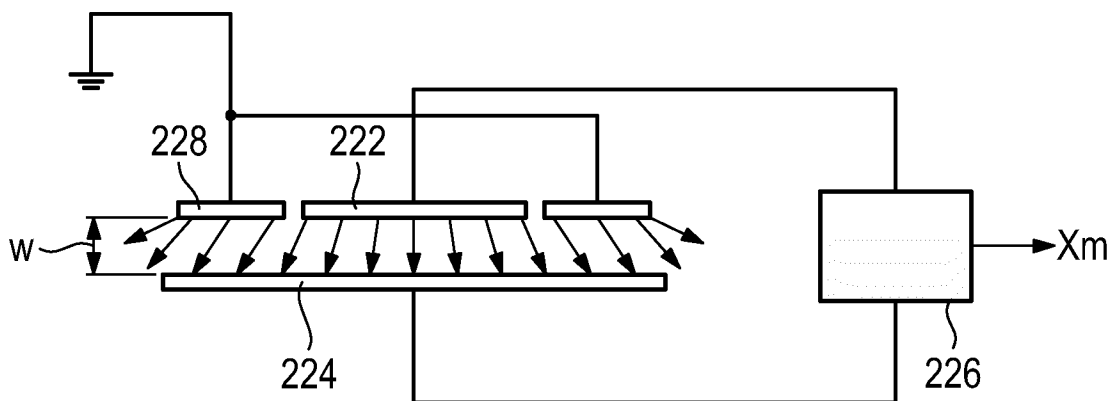
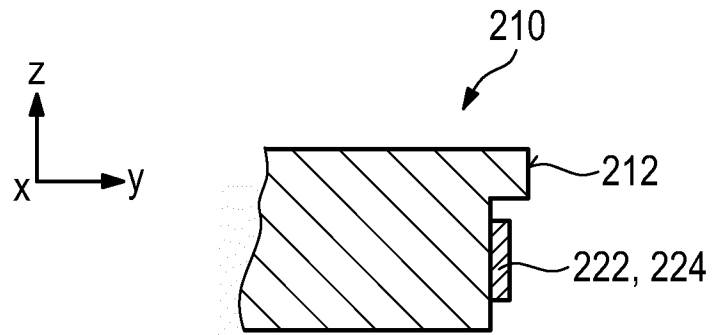
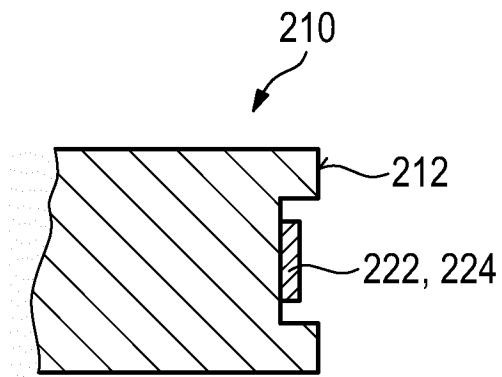
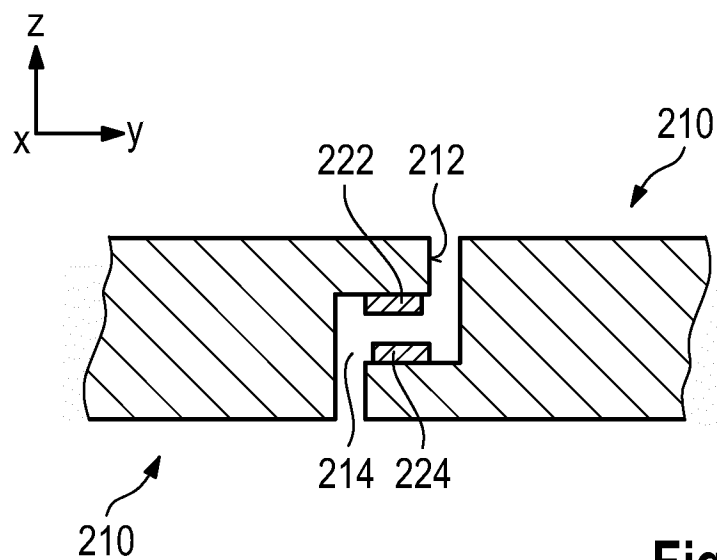


Fig. 4

**Fig. 5A****Fig. 5B****Fig. 6**

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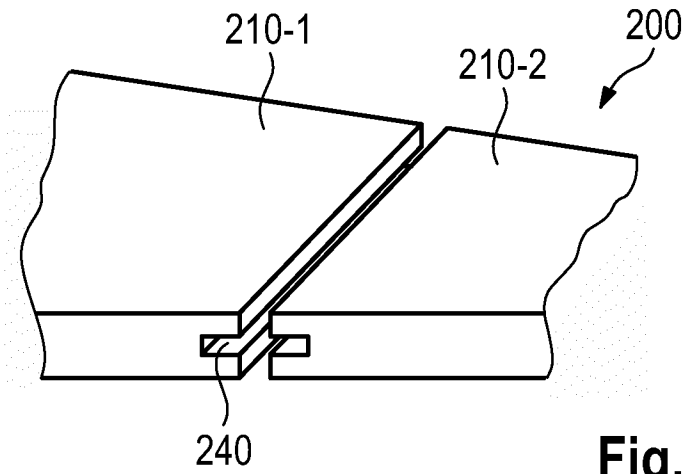


Fig. 7

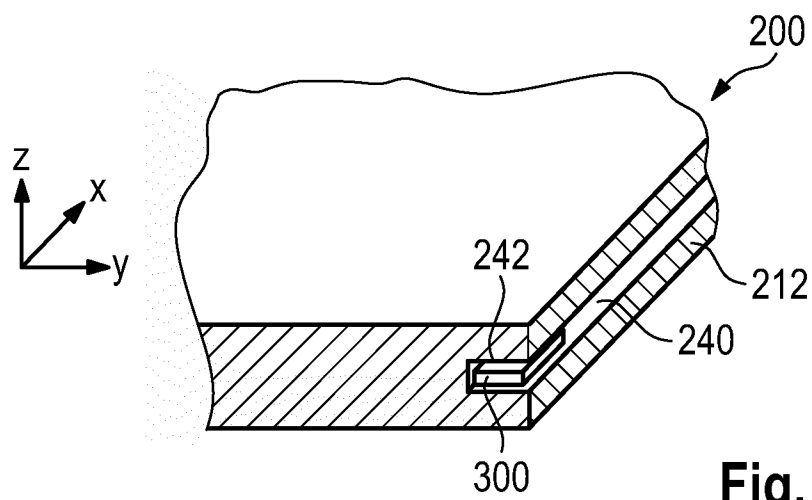


Fig. 8

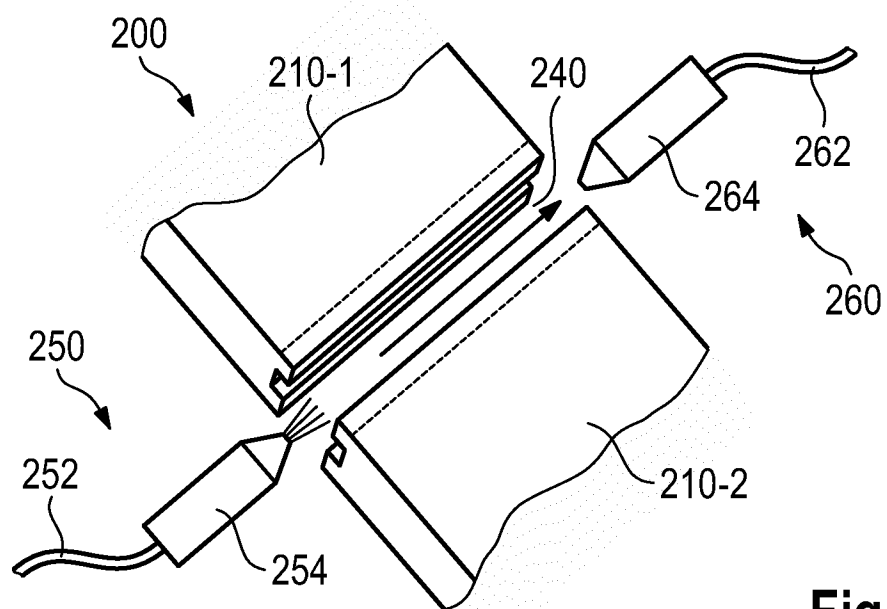


Fig. 9

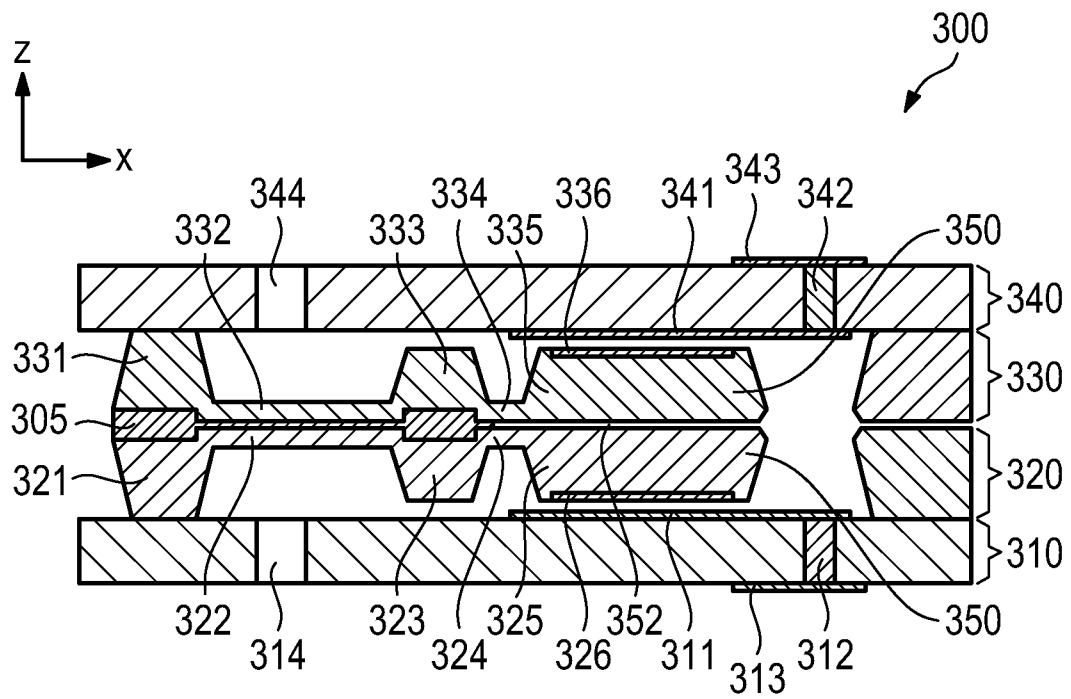


Fig. 10

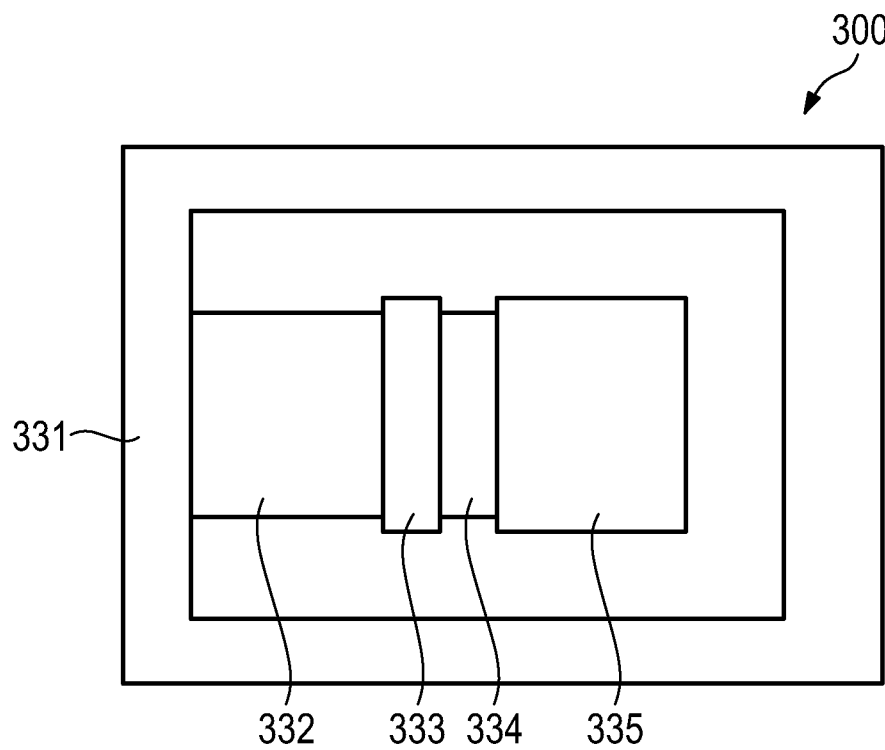


Fig. 11

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/062735

A. CLASSIFICATION OF SUBJECT MATTER

INV. G01L21/00 G01B7/14 G01B13/12 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)

G01L 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, INSPEC, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2012/059537 A1 (ZEISS CARL SMT GMBH [DE]; ENKISCH HARTMUT [DE]; MUELLENDER STEPHAN [DE] 10 May 2012 (2012-05-10)	1,2,4,5, 11-19
Y	page 3, line 27 - page 4, line 2 page 20, lines 1-19 figures 1, 6	3,6,7
Y	----- US 2004/227915 A1 (OHTSUKA MASARU [JP]) 18 November 2004 (2004-11-18) paragraphs [0081] - [0084]; figure 1	3
Y	----- EP 1 569 035 A1 (ASML NETHERLANDS BV [NL]) 31 August 2005 (2005-08-31) paragraphs [0082] - [0084]; figure 9	6,7



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

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"&" document member of the same patent family

Date of the actual completion of the international search

10 October 2013

Date of mailing of the international search report

21/10/2013

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2013/062735

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2012059537 A1	10-05-2012	CN 103189800 A	03-07-2013
		DE 102010043498 A1	10-05-2012
		EP 2635937 A1	11-09-2013
		TW 201239542 A	01-10-2012
		US 2013242278 A1	19-09-2013
		WO 2012059537 A1	10-05-2012

US 2004227915 A1	18-11-2004	JP 2004266264 A	24-09-2004
		US 2004227915 A1	18-11-2004

EP 1569035 A1	31-08-2005	CN 1684002 A	19-10-2005
		EP 1569035 A1	31-08-2005
		JP 4694221 B2	08-06-2011
		JP 5044513 B2	10-10-2012
		JP 5044514 B2	10-10-2012
		JP 2005244238 A	08-09-2005
		JP 2008306216 A	18-12-2008
		JP 2009021625 A	29-01-2009
		JP 2009044165 A	26-02-2009
		KR 20060042384 A	12-05-2006
		SG 114755 A1	29-11-2006
		TW I282489 B	11-06-2007
		US 2005190353 A1	01-09-2005
		US 2006256309 A1	16-11-2006
