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(54) Method of determining a position of a substrate in a lithography system, substrate for use in such method, and lithography system for carrying out such method.

(57) The invention relates to a substrate (12,513) comprising an optical position mark (100) for being reed-out by en optical recording head (500) for emitting light of predetermined wavelength, preferably red or infra-red light more in particular of 635 nm light, the optical position mark (100) having a mark height (MH), a mark length (ML) and a predetermined known position on the substrate (12,513), the optical position mark (100) extending along a longitudinal direction (x) and being arranged for varying a reflection coefficient of the position mark (100) along said longitudinal direction (x), wherein the optical position mark (100) comprises:
- a first region (101) having a first reflection coefficient and a first width (W);
- a second region (102) neighboring the first region (101) and forming a first region pair (105), the second region (102) having a second reflection coefficient and a second width (W), and the second reflection coefficient being different from the first reflection coefficient, wherein the first region (101) comprises sub-wavelength structures (SWS) in comparison with a wavelength of the predetermined wavelength light.

Method of determining a position of a substrate in a lithography system, substrate for use in such method, and lithography system for carrying out such method.

FIELD OF THE INVENTION

The present invention relates to method of determining a position of a substrate in a lithography system, the system comprising an optical alignment sensor for emitting a light beam to the substrate and for measuring an intensity profile of a zero-th order reflected light beam. The invention also relates to an optical position mark for use in such method. The invention further relates to a lithography system for processing a substrate and being configured for carrying out such method.

BACKGROUND OF THE INVENTION

Position determination in lithography systems is generally known, normally using detection of light reflected in several diffraction orders, as is described for instance in US patent no. 4,967,088. A disadvantage of determining a position using light reflected in several diffraction orders is that the light detectors for the different diffraction orders have to be accurately positioned in the system, thus increasing the cost of the system. Moreover, such systems are sensitive to slight errors in focus of the light beam or tilt of a substrate relative to the light beam.

US5,827,629 discloses a similar system, wherein a wafer with an exposure surface and an exposure mask are disposed. The exposure surface is directed to the exposure mask with a gap being interposed therebetween. The wafer has a position aligning wafer mark formed on the exposure surface. The wafer mark has a linear or point scattering source for scattering incident light, and the exposure mask has a position aligning mask mark having a linear or point scattering source for scattering incident light. A relative position of the wafer and exposure mask is detected by applying illumination light to the wafer mark and mask mark and by observing scattered light from the scattered sources of the wafer mark and mask mark. In order to at least partially overcome the problems of the above-mentioned prior-art, it has been suggested by the inventors to provide a substrate comprising a checkerboard pattern of reflective squares, having a maximum reflection coefficient, and non-reflective squares, having a minimum reflection coefficient, wherein said squares have a width corresponding to a diameter of a cross-section of a light beam projected on said pattern. By measuring a reflected zero-th order intensity of the beam, a change in position of the beam relative to the substrate can be determined without measuring multiple diffraction orders. Ideally, when the beam spot of the light beam is moved over the pattern, the intensity of the reflected signal is a sinusoidal function with high contrast of the position of the beam spot on the pattern. However, in practice the intensity distribution of the beam spot generally does not correspond to a homogeneous and sharply cut-off disc-like profile but instead follows a Gaussian profile, the resulting reflected intensity signal does not closely resemble a sinusoid function as a function of the position of the beam on the substrate. As a result, the determination of the position of the beam spot on the substrate based on the intensity of the reflected beam is less accurate.

US7,418,125B2 discloses an apparatus for detecting a position of a region, corresponding to a mark, in image data, as a mark position, the mark including periodically arranged patterns. A first unit obtains a real-space energy distribution which corresponds to an energy spectrum distribution of each partial area of the image data. A probability distribution obtaining unit obtains a probability distribution based on the real-space energy distribution, the probability distribution indicating repetitive positions of the periodically arranged patterns and the intensity of periodicity at this position. A second unit obtains a degree of correlation between each probability distribution obtained by the probability distribution obtaining unit and a pre-registered probability distribution of the mark, and a third unit obtains the mark position based upon the degrees of correlation obtained by the second unit.

All of the above-mentioned methods of determining a position of a substrate in a lithography system are cumbersome, complex, and suffer from draw-backs, such as inaccuracy.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a method of determining a position of a substrate in a lithography system, which is simple and provides a very high accuracy (including a high reproducibility and repeatability).

It is a further object of the invention to provide an optical position mark for use in such method, and a lithography system configured for carrying out such method.

The invention is defined by the independent claims. The dependent claims define advantageous embodiments.

To this end, according to a first aspect, the present invention provides a substrate comprising an optical position mark for being read-out by an optical recording head for emitting light, preferably red or infra-red light, the optical position mark having a mark height, a mark length and a predetermined known position on the substrate, the optical position mark extending along a longitudinal direction and being arranged for varying a reflection coefficient of the position mark along said longitudinal direction, wherein the optical position mark comprises:

- a first region having a first reflection coefficient and a first width;
- a second region neighboring the first region and forming a first region pair, the second region having a second reflection coefficient and a second width, the first width being equal to the second width measured in the longitudinal direction, and the second reflection coefficient being different from the first reflection coefficient, wherein the first region comprises sub-wavelength structures in comparison with a wavelength of the light, such as 635nm.

The advantage of the substrate of the invention is that the provision of sub-wavelength structures in the first region increases process tolerance of the position mark. This may be understood as follows. The sub-wavelength structures may be made using conventional lithography or processing techniques. Assuming that one of said sub-wavelength structures is not correctly manufactured or maybe even absent, the mark may still be used without loosing too much accuracy. A second effect is that sub wavelength features cause less sensitivity to height variations in the optical position mark when used in the invention. Furthermore, the substrate according to the invention has an extremely regular structure, i.e one width and one spacing throughout the position mark. Such large regularity results in a position mark, which is much easier to design and the risk of design errors is thereby strongly reduced (expressed differently, the chance that a simple optical position mark is designed wrong is much lower than that of complex optical position marks). Furthermore the verifiability is much higher of such design. Consequently, the systematical reproducibility is much better using segmented mark design as prescribed in the invention.

In an embodiment the first width is equal to the second width measured in the longitudinal direction. Such structure provides for an even larger regularity.

In an embodiment the sub-wavelength structures comprise a plurality of regular stripe-shaped segments extending in a further direction perpendicular to the longitudinal direction, wherein each regular segment is formed by a first sub-region and a second sub-region. This is a first variant of making regular sub-wavelength structures, and experiments have shown that the results with these marks are very good.

In an embodiment the sub-wavelength structures comprise a plurality of regular stripe-shaped segments extending in the longitudinal direction, wherein each regular stripe-shaped segment is formed by a first sub-region and a second sub-region. This is a second variant of making regular sub-wavelength structures, and experiments have shown that the results with these marks are very good, and even slightly better than the first variant.

An embodiment further comprises a plurality of additional region pairs, wherein each additional region pair is substantially equal to the first region pair. The regularity of such structure is very advantageous as discussed before. Moreover, the more region pairs the more features. This is advantageous in case cross-correlation is used for measuring the displacement of the position mark with regards to the expected position (i.e. by comparing a measured intensity graph with an expected intensity graph).

In an embodiment the first width and the second width are in a range between 1 μm and 2 μm. The advantage of this range is that it is larger than a spot size of a conventional optical read head, which is typically in the range of 1 μm to 2 μm. The effect is that the contrast in reflected beam intensity between the first and second region is higher.

In an embodiment the mark length is at least 100 μm. The longer the mark length the more accurate the mark position may be determined using cross-correlation measurement, i.e. cross-correlating a larger region results in a higher peak in the cross-correlation curve.

In an embodiment the sub-wavelength structures provide for the first reflection coefficient being lower than the second reflection coefficient. The sub-wavelength structures in this embodiment effectively absorb the light beam from the optical read head, which severely reduces the reflection coefficient of the first region.

In an embodiment the first region pair and the plurality of additional region pairs form a first main region. The substrate further comprises a second main region neighboring the first main region, wherein the second main region is substantially free of structures. The addition of the second region that is substantially free of structures increases the process tolerance of the optical position mark and improves the cross-correlation measurement, i.e. the cross-correlation function shows a higher and sharper peak.

In an embodiment a third main region neighboring the second main region, wherein the second main region is embedded between the first main region and the third main region when viewed in the longitudinal direction. The advantage of this embodiment is that the position mark may be very easily detected optically, due to the two separated regions. This enables a quick estimation of the position of the optical position mark when using a microscope, for example.

In an embodiment the third main region is build up in a similar manner as the first region comprising sub-wavelength structures. This embodiment provides for a larger regularity and is thereby less process-dependent, and has a larger verifiability.

In an embodiment the first main region and the third main region are substantially identical. This embodiment provides for an even larger regularity and is thereby less process-dependent, and has an even larger verifiability.

In an embodiment the first region and the third region are different (length, pitch, number of structures, etc). Making the first and second region different from each other provides additional information, namely the orientation of the mark in comparison with the scan direction of the optical head, i.e. left and right side are distinguishable.

An embodiment further comprises a first end region located at a first end of the optical position mark neighboring the first main region, the first end region being substantially free of structures. The addition of an end region that is substantially free of structures increases the process tolerance of the optical position mark and improves the cross-correlation measurement, i.e. the cross-correlation function shows a higher and sharper peak.

In an embodiment further comprises a second end region located at a second end of the optical position mark neighboring the third main region, the second end region being substantially free of structures. The addition of an end region that is substantially free of structures increases the process tolerance of the optical position mark and improves the cross-correlation measurement, i.e. the cross-correlation function shows a higher and sharper peak.

In an embodiment the mark height is a plurality of times the wavelength of the red or infra-red light. In an embodiment the mark height is larger as possible to provide for the highest tolerance to position errors in that direction. However, the mark height is preferably smaller than 40 μm such that it fits within a scribe line, which typically has such width.

To this end, according to a second aspect, the present invention provides a lithography system for processing a substrate according to the invention as defined in claims 1 to 14, the system comprising:

- a substrate exposure means for exposing the substrate;
- a substrate carrier for receiving said substrate, wherein the substrate carrier is movable with respect to the substrate exposure means for allowing exposure of different parts of said substrate, and
- an optical alignment sensor mounted to the system such that it has a substantially constant distance from the substrate exposure means, the optical alignment sensor being configured for emitting a light beam to the substrate and for measuring an intensity profile of a zero-th order reflected light beam,

wherein the lithography system is configured for carrying out the method of the invention as defined in claims 22 to 31.

The lithography system of the invention makes use of measuring an intensity of a zero-th order reflected light beam, in contrast to the first and higher-order measurements known from the prior art. The substrate of the invention may be conveniently used with the substrate of the invention. Whereas in the prior art solutions some sort of linear or sinusoidal varying of the intensity of the reflected light beam is required in the invention no such requirement is there at all. As will be explained with regards to the method of the invention, the invention only requires a varying reflectivity resulting in varying intensity of the reflected beam. Once the intensity graph of the position mark is known, the only thing that is required in the invention is to compare a measured intensity graph with the known intensity graph to determine the actual position of the optical position mark.

In an embodiment further comprises a further optical alignment sensor mounted to the system such that it has a further substantially constant distance from the substrate exposure means, the optical alignment sensor being configured for emitting a further light beam to the substrate and for measuring an intensity profile of a zero-th order reflected light beam, the lithography system being configured for allowing said optical alignment sensor scanning in a first direction, and the lithography system being configured for allowing said further optical alignment sensor scanning in a second direction orthogonal to said first direction. This embodiment provides a second alignment sensor in the system and dedicates each of said sensors for scanning a specific one of said directions. The advantage is that each of said sensors only determines one coordinate and provides a tolerance for the other coordinate (not being measured) at the same time (due to the fact that the 1-D optical position mark extends in a longitudinal direction only, i.e. the other dimension provides a position tolerance at the same time).

In an embodiment the first direction coincides with a first movement direction of the substrate in operational use of the lithography system, and the second direction coincides with a second movement direction of the substrate in operational use of the lithography system. Such division of the measurements over both optical alignment sensors is particularly advantageous in case both alignment sensors are positioned on orthogonal axis that cross in a center of the substrate exposure system.

An embodiment comprises a driver stage for moving and positioning said substrate carrier with respect to the substrate exposure means. The driver stage effectively completes the lithography system, which may be a photolithography system, an E-beam lithography system, and an ion-beam lithography system.

In an embodiment the substrate exposure means comprises an optical column adapted for projecting one or more exposure beams on the substrate, wherein said alignment sensors are mounted to the optical column.

In an embodiment the optical column is configured for projecting a multitude of charged particle exposure beams, such as electron beams, on the substrate.

To this end, according to a third aspect, the present invention provides a method of determining a position of a substrate in a lithography system, the system comprising an optical alignment sensor for emitting a light beam to the substrate and for measuring an intensity profile of a zero-th order reflected light beam. The method comprises:

- providing a substrate comprising an optical position mark having a mark width, a mark length and a predetermined known position on the substrate, the optical position mark extending along a longitudinal direction and being arranged for varying a reflection coefficient of the position mark along said longitudinal direction;
- moving the substrate such that the optical position mark is substantially near the optical alignment sensor in accordance with an estimated position of the optical position mark with regards to the optical alignment sensor;
- scanning the optical position mark along a scan path in the longitudinal direction with the optical alignment sensor to obtain a measured intensity profile having a scan length, wherein the scan length is longer than the mark length;
- comparing the measured intensity profile with an expected intensity profile associated with the optical position mark to determine a difference between an actual position of the optical position mark and the estimated position, and
- determining the actual position of the position mark from the scan path and said difference.

The method provides a quick and efficient way of determining the position of the substrate (one coordinate is determined, for example an x-coordinate or a y-coordinate). In lithography systems interferometers may be used to determine a position of a chuck or a substrate on the chuck with respect to the projection optics. Furthermore the lithography system is provided with at least one optical alignment sensor, wherein, in the current method, this optical alignment sensor preferably has a constant and known distance with respect to the substrate exposure means in a lithography system. Once the optical position marker is known, an intensity profile can be measured or simulated of this marker, which provides the expected intensity profile. An interesting aspect of this method is that the position of the substrate relative to the optical alignment sensor at first only needs to be estimated, i.e. needs to be known with a limited accuracy, for instance ±20μm. The tolerance for this inaccuracy is mainly determined by the mark width in the transversal direction. Using this estimated position the substrate is moved such that the optical position mark is substantially near the optical alignment sensor. The optical alignment sensor subsequently scans the optical position mark with a scan length longer than the mark length to obtain a measured intensity profile. The latter creates the tolerance for the inaccuracy of the estimated position in the longitudinal direction. In a next step the measured intensity profile is compared with the expected intensity profile. In most cases the measured intensity profile will be to some extent a shifted (but maybe somewhat deformed) version of the expected intensity profile, wherein the shift is indicative for the actual position of the optical position mark relative to the optical alignment sensor. This shift combined with a start location of the scan provides the actual position of one end of the position mark. In embodiments a position of a center of the optical position mark will be considered to be the position of the optical position mark.

Non-published international application WO 2012/144904 describes a substrate for use in a lithography system. Said substrate is provided with an at least partially reflective position mark comprising an array of structures. The array extends along a longitudinal direction of the mark. Said structures are arranged for varying a reflection coefficient of the mark along the longitudinal direction, wherein said reflection coefficient is determined for a predetermined wavelength. The present application provides an improvement on WO 2012/144904.

In an embodiment of the method the step of comparing of the measured intensity profile with the expected intensity profile comprises:

- calculating a cross-correlation function between said profiles, and
- determining a location of a maximum in said cross-correlation function, wherein said location is indicative for said difference. A first advantage of this embodiment is that it is much more marker tolerant as long as the marker is known as well as the expected intensity profile associated with this marker. Even a simple marker in accordance with the invention may be used, whereas in prior art solution much more requirements exist for the marker. Moreover, the method is more tolerant for the accuracy of the expected intensity profile. Cross-correlation is a very advantageous method of determining a shift between said intensity profiles, particularly when there is large "deformation" or mismatch of the intensity profile, when comparing the expected intensity profile with the measured intensity profile.

In an embodiment of the method, in the step of providing the substrate, the substrate comprises a further optical position mark having a further mark width, a further mark length and a further predetermined known position on the substrate, the further optical position mark extending along a further longitudinal direction and being arranged for varying a further reflection coefficient of the further position mark along said further longitudinal direction, wherein said further longitudinal direction is orthogonal to said longitudinal direction, wherein the optical position mark and the further optical position mark form a position mark couple the method further comprising, after the step of scanning the optical position mark, steps of:

- moving the substrate such that the further optical position mark is substantially near the optical alignment sensor in accordance with a further estimated position of the further optical position mark with regards to the optical alignment sensor;
- scanning the further optical position mark along a further scan path in the further longitudinal direction with the optical alignment sensor to obtain a further measured intensity profile having a further scan length, wherein the further scan length is longer than the further mark length;
- comparing the further measured intensity profile with a further expected intensity profile associated with the further optical position mark to determine a further difference between a further actual position of the further optical position mark and the further estimated position, and
- determining the further actual position of the further position mark from the further scan path and said further difference. As the optical position mark in accordance with the invention only provides one coordinate of the optical position mark (namely on a first axis extending in the longitudinal direction of the optical position mark). This embodiment provides the second coordinate of the position, the second coordinate corresponding to an axis in a second direction orthogonal to a first axis of the first coordinate.

In an embodiment of the method the step of comparing of the further measured intensity profile with the further expected intensity profile comprises:
- calculating a further cross-correlation function between said profiles, and
- determining a further location of a maximum in said further cross-correlation function, wherein said further location is indicative for said difference.

A first advantage of this embodiment is that it is much more marker tolerant as long as the marker is known as well as the expected intensity profile associated with this marker. Even a simple marker in accordance with the invention may be used, whereas in prior art solution much more requirements exist for the marker. Moreover, the method is more tolerant for the accuracy of the expected intensity profile. Cross-correlation is a very advantageous method of determining a shift between said intensity profiles, particularly when there is large "deformation" or mismatch of the intensity profile, when comparing the expected intensity profile with the measured intensity profile.

In an embodiment of the method the lithography system comprises a further optical alignment sensor for emitting a further light beam to the substrate and for measuring an intensity profile of a zero-th order reflected light beam, the lithography system being configured for allowing said optical alignment sensor scanning only in a first direction, and the lithography system being configured for allowing said further optical alignment sensor scanning only in a second direction orthogonal to said first direction, wherein, in the step of providing the substrate the longitudinal direction of the optical position mark coincides with the first direction and the further longitudinal direction of the further optical position mark coincides with the second direction,

wherein, in the respective steps of scanning, the optical alignment sensor is used for scanning the optical position mark and the further optical alignment sensor is used for scanning the further optical position mark. The advantage is that each of said sensors only determines one coordinate and provides a tolerance for the other coordinate (not being measured) at the same time (due to the fact that the 1-D optical position mark extends in a longitudinal direction only, i.e. the other dimension provides a position tolerance at the same time).

In an embodiment of the method the first direction coincides with a first movement direction of the substrate in operational use of the lithography system, and the second direction coincides with a second movement direction of the substrate in operational use of the lithography system. Such division of the measurements over both optical alignment sensors is particularly advantageous in case both alignment sensors are positioned on orthogonal axis that cross in a center of the substrate exposure system.

In an embodiment of the method, in the step of providing the substrate, the substrate comprises a second optical position mark couple being located at a different location on the substrate, wherein the second optical position mark couple is similar to a first optical position mark couple, and wherein the method is repeated for said second optical position mark couple. This embodiment_enables measurement of rotational orientation of the substrate.

The various aspects and features described and shown in the specification can be applied, individually, wherever possible. These individual aspects, in particular the aspects and features described in the attached dependent claims, can be made subject of divisional patent applications.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be elucidated on the basis of an exemplary embodiment shown in the attached drawings, in which:

Fig. 1 shows a prior art lithography system in which the substrate according to the invention may be used,

Fig. 2 shows a prior art positioning system, for determining a position of a target relative to an optical column,

Fig. 3 schematically shows a position device adapted for providing a beam for cooperation with a substrate according to the invention, and for detecting an intensity of a reflection of said beam in said substrate, and

Fig. 4 shows a schematic detail of a position device according to the present invention.

Fig. 5 shows part of a lithography system of the invention;

Fig. 6 shows a modeled intensity profile belonging to the substrate comprising the optical position mark of the invention;

Fig. 7 shows a measured intensity profile using the lithography system of the invention;

Fig. 8 shows a calculated cross-correlation function between the charts of Figs. 6 and 7;

Fig. 9 schematically shows a substrate comprising an optical position mark according to the invention;

Fig. 10 shows another embodiment of the optical position mark according to the invention combined with measured intensity profiles of such mark for different mask stacks.;

Fig. 11 shows a zoom view of the profiles of Fig. 10, wherein the zoom view is bounded by the dashed rectangle of Fig. 10;

Fig. 12 shows another embodiment of the optical position mark according to the invention combined with a zoom view of the measured intensity profiles of such mark for different mask stacks;

Fig. 13 shows another embodiment of the optical position mark according to the invention combined with a zoom view of the measured intensity profiles of such mark for different mask stacks;

Fig. 14 shows another embodiment of the optical position mark according to the invention combined with a zoom view of the measured intensity profiles of such mark for different mask stacks;

Fig. 15 shows another embodiment of the optical position mark comprising sub-wavelength features according to the invention combined with a zoom view of the measured intensity profiles of such mark for different mask stacks;

Fig. 16 shows another embodiment of the optical position mark comprising sub-wavelength features according to the invention combined with a zoom view of the measured intensity profiles of such mark for different mask stacks;

Fig. 17 shows another embodiment of the optical position mark comprising sub-wavelength features according to the invention combined with a zoom view of the measured intensity profiles of such mark for different mask stacks;

Fig. 18 shows the reproducibility results of the optical position marks of Figs. 10, 12, 13, 14, 15, 16 and 17 for each optical alignment sensor in the lithography system;

Fig. 19 shows accuracy results of the optical position marks of Figs. 10, 12, 13, 14, 15, 16 and 17 for each optical alignment sensor in the lithography system, and

Fig. 20 shows a more detailed view of the optical position mark of Fig. 9.

List of refererence numerals

2	source
3	charged particle beam
4	collimator
5	aperture array
6	multitude of charged particle beamlets
7	condenser array
8	beam blanker array
9	beam stop array
10	scanning deflector
11	focusing lens array
12	target (i.e. wafer)
13	moveable target carrier
14	optical column
L	long-stroke direction
S	short-stroke direction
15,16	straight edges or mirrors
21a,21b, 23a,23b	one or more beams
20,22	interferometers
P1, P2, P3	respective points of the target
500	position device
550	beam spot
513	substrate (= target 12)
571	beam absorbing structures
511	light beam
536	beam splitter
512	focusing lens
519	beam intensity detector (photodiode)
560	graph
531	beam source
534	laser

532	optical fiber
533	optical system
535	collimator lens
518	reflected beam
536'	polarizing beam splitter
511'	polarized light beam
538	polarizer
539	quarter wave plate
PO	projection optics
SMRK	first position mark (for measuring one coordinate only)
DMRK	second position mark (for measuring one coordinate only)
Xw	x-coordinate of substrate
Yw	y-coordinate of substrate
SS	first optical alignment sensor
DS	second optical alignment sensor
OO	center of projection optics (origin)
Rz	angular error of the chuck around z-axis
LN	lane
I	light intensity
CRC	cross-correlation coefficient
TPR	top region of cross-correlation curve
100	optical position mark
101	first region having first reflectivity
102	second region having second reflectivity
105	region pairs
110	first main region
120	second main region
130	third main region
140	end regions
ML	mark length
MH	mark height
W	width of first region
SWS	sub-wavelength structures
PSW	pitch sub-wavelength structures
P	pitch of region pair
100-1	optical position mark without sub-wavelength structures
100-2	optical position mark with sub-wavelength structures having longitudinal

	segmentation
100-3	optical position mark with sub-wavelength structures having transversal segmentation
WFR1	first wafer (substrate) having no masking layer stack
WFR2	second wafer (substrate) having thin masking layer stack
WFR3	third wafer (substrate) having thicker masking layer stack
WFR4	fourth wafer (substrate) having even thicker masking layer stack
WFR5	fifth wafer (substrate) having thickest masking layer stack
MRK1	first optical position mark (pitch 1 μm, non-segmented)
MRK2	second optical position mark (pitch 2 μm, non-segmented)
MRK3	third optical position mark (pitch 3 μm, non-segmented)
MRK4	fourth optical position mark (pitch 4 μm, non-segmented)
MRK5	fifth optical position mark (pitch 2 μm, longitudinally segmented)
MRK6	sixth optical position mark (pitch 2 μm, transversally segmented)
MRK7	seventh optical position mark (pitch 2 μm, segmented both longitudinally and transversally)

DETAILED DESCRIPTION OF THE INVENTION

A known lithography system is shown in Fig. 1. The lithography system 1 comprises a charged particle beam source 2 which emits a charged particle beam 3. Charged particle beam 3 traverses a collimator 4 before impinging on an aperture array 5. The aperture array splits the beam into a multitude of charged particle beamlets 6 which are condensed by condenser array 7. At beam blanker array 8 individual beamlets may be blanked, i.e. may be individually deflected such that they encounter beam stop array 9 later on in their trajectories instead of passing through apertures in beam stop array 9. The beamlets that have not been blanked then pass through a scanning deflector 10 which is adapted to provide a scanning deflection of said beamlets. At the end of their trajectories the beamlets that have not been blanked pass through a focusing lens array 11 adapted for focusing said beamlets onto a surface of a target 12, for instance a wafer. The target is placed on a moveable target carrier 13, adapted for displacing the target relative to optical column 14 along a long-stroke direction L, using a long-stroke actuator. The target carrier is further adapted for displacing the target along a short-stroke direction S by means of a short-stroke actuator. The short-stroke actuator may further comprise a 6 degree of freedom actuator, for fine tuning translation of the target in three orthogonal directions, and for fine tuning rotation of the target along three orthogonal axes. Typically a target 12 is exposed in a strip-by-strip fashion by moving the target under the optical column 14 using the long stroke actuator while exposing the target 12 to beamlets that may be deflected along the width of a strip along the short-stroke direction by the scanning deflector 10. When an entire strip has thus been patterned, the short stroke actuator may be used to displace target a distance corresponding to the width of the strip in the S direction, and the next strip may be processed.

When structures span more than one strip, or when a strip of the target is to be processed in multiple passes, for instance when patterning different layers of a semiconductor device, it is essential that the overlain layers can be aligned to within a specified accuracy. Such alignment may be achieved by accurately positioning the target 12 relative to the optical column 14.

Fig. 2 shows a schematic top view of a prior art position measurement system for use in a lithography system, in which the position of the optical column 14 is measured relative to a target carrier 13 carrying a target 12. The target 12 is partitioned into strips along the long-stroke direction L. Patterning of the target 12 may commence when point p1 of the target is placed under the optical column 14 of a lithography system. Because of the scanning deflection of the beamlets, any part of the strip can be reached by the beamlets when the target 12 is moved under the optical column 14 by the long-stroke actuator of the lithography system. When point P2 of the target 12 is under the optical column 14, the short-stroke actuator may be used to move the target in a direction perpendicular to the long-stroke direction L, such that point P3 of the target is placed directly underneath the optical column 14, and the next strip may be processed. Target carrier 13 is provided with straight edges 15,16, or mirrors, wherein edge 15 is perpendicular to the long-stroke direction L, and edge 16 is perpendicular to short-stroke direction S. The edges 15,16 are adapted reflecting one or more beams 21a,21b, 23a,23b respectively from interferometers 20,22 for keeping track of a change in distance between said interferometer and edge 15 and 16 respectively of the target carrier 13. Based on any changes in these distances a position of the target 12 relative to the optical column 15 is calculated, i.e. the position is obtained indirectly as a function of change in the distance along the long- or short-stroke directions. Any changes in said distance will lead to a change in the calculated position, even if the changes in distance are not caused by a long-stroke or short-stroke actuator of the system. For instance, when the edge 15 deforms, changing the tilt of the edge and/or changing the focus of interferometer beam 21a incident on the edge 15, the calculated position of the target 12 relative to the optical column 14 will change. Moreover, any changes in the position or orientation of the interferometer 20 will affect the calculated position as well.

Fig. 3 schematically shows a position device 500 according to the invention, for detecting an alignment and/position of a beam spot 550 on a substrate 513 according to the invention. The substrate 513 comprises a partially reflective surface, said surface having a substantially constant reflection coefficient, and provided with beam absorbing structures 571, which vary a specular reflection coefficient of the substrate along the longitudinal direction L. A light beam 511 of a predetermined wavelength is passed through beam splitter 536 and is focused by focusing lens 512 onto a spot on the substrate 513, and partially reflected therein. The intensity of the reflected beam is detected by beam intensity detector 519. Graph 560 shows a plot of the detected beam intensity vs. position of the spot on the substrate, when the substrate is moved along the longitudinal, or long-stroke, direction L. The position device is adapted for alignment of a beam spot on a substrate. This is particularly useful when several layers of patterns are overlain during separate processing sessions of a same target. Once the target has been aligned the position may be tracked using other position measuring means known in the art, such as interferometers.

Alternatively, the position device may be used to track a position of the beam on the substrate during processing of the target, e.g. during preparation and/or exposure of a target in a lithography system, based on the number of peaks encountered in the detected intensity signal. Based on the number of peaks encountered and the actual detected intensity value, an even more accurate position can be determined.

Fig. 4 schematically shows a position device 500 according to the invention in more detail. The position device is adapted for detecting the position of a beam spot 550 on a substrate 513 according to the invention. Beam source 531 comprises a laser 534 for providing a light beam 511 with a wavelength in the range of 600-650 nm, or about 635 nm. The beam source 531 further comprises an optical fiber 532 for guiding the light beam 511 from the laser 534 towards the optical system 533. The beam leaving the optical fiber 532 preferably has a nearly perfect Gaussian profile and may be easily collimated. The beam source comprises a collimator lens 535 arranged for collimating the beam 511 from optical fiber 532. However, when a fiber is not used and the laser or another beam generating device is providing a collimated beam, such a collimating lens 535 may not be required.

The optical system 533 further comprises a beam splitter 536, for directing the beam 511 towards surface of the substrate 513. A focusing lens 512 of the optical system focuses beam 511 on the surface 513. The reflected beam 518 is generated by specular reflection of the beam 511 in the substrate 513. The focus lens 512 may also be used for collimating the reflected beam 518. The reflected beam 518 is directed towards the beam intensity detector 519 by beam splitter 536.

The beam intensity detector 519 comprises a photodiode. Alternatively is may comprise an un-biased silicon PIN diode working in the photovoltaic mode. This mode may lower the amount of heat generated with respect to a biased mode operation of a photodiode. The beam intensity detector may also comprise an operational amplifier to convert the current from the photodiode into a voltage which may be filtered. The filtered voltage may be converted to a digital signal that may be used by a processor for determining a position or displacement of the surface 513 relative to the optical system 533.

The active area of the beam intensity detector 519 is larger than the diameter of the reflected light beam leaving the beam splitter so that substantially all of the energy leaving the beam splitter is detected. However, another focus lens (not shown) located between the beam splitter 536 and the beam intensity detector 519 may be used for focusing the reflected light beam on the beam intensity detector 519. In this way the effective area of the beam intensity detector may be smaller than the diameter of the reflected light beam leaving the beam splitter 536.

In a non-polarizing beam splitter 536 it may be the case that 50% of the light beam 511 is directed towards the substrate 513, while the other 50% may be lost. And of the reflected light beam only 50% may be directed to the beam intensity detector 519, while the other 50% may be lost. This implies that 75% of the light beam 511 is lost, i.e. is not used for the position and/or alignment detection.

Therefore, a polarizing beam splitter 536' may be used in an embodiment of the mark position detector device according to the invention. In that case, the beam source 531 may provide a polarized light beam 511'. The beam source may comprise a polarizer 538 arranged for transforming a non-polarized light beam into a polarized light beam 511. Light beam 511 may be an S-polarized light beam, which is indicated in the figure by a dot.

The polarizing beam splitter 536' may be arranged for guiding the S-polarized light beam towards the surface of the substrate. The optical system may further comprise a quarter wave plate 539, which may be located between the beam splitter 536' and the focus lens 512. When the light beam 511' travels through the quarter wave plate 539, it its polarization is changed from S-polarization into a right circular polarization, as is indicated by a curved arrow in the figure. When the beam 511' is reflected by the surface 513, polarization may change again: the reflected light beam may have a left circular polarization, as is indicated by another curved arrow in the figure. When the reflected light beam 518 travels through the quarter wave plate 539, its polarization is changed from left circular polarization into a P-polarization which is indicated by a straight arrow in the figure. Polarizing beam splitter 536' is arranged to guide the P-polarized reflected light beam towards the light intensity detector 519.

The use of a polarized light beam 511' and reflected light beam 518 and a polarizing beam splitter 536' results in a reduction of stray light, back reflection and energy loss in the beam splitter 536'.

Fig. 5 shows part of a lithography system of the invention. This part comprises the movable target carrier (or chuck) As discussed earlier the position of the chuck is determined using the one or more beams 21a, 21b, 23a, 23b from interferometers (not shown). Such position is determined with respect to the projection optics PO of the lithography system. However, despite the fact that the position of the chuck 13 is known, still the exact position of the target 12 (substrate or wafer) with respect to the projection optics PO is not known. Special clamping measures can be taken such that the position and orientation of the substrate 12 on the chuck 13 is known with limited accuracy, for example +- 20 μm, referred to a the coarse position hereinafter. The substrate 12 is provided with optical position marks SMRK, DMRK which have a known position with regards to the coordinate frame of the wafer. The exact positions, i.e. wafer coordinates Xw, Yw of the optical position marks with respect to the projection optics PO are determined using the knowledge of the coarse position of the optical position marks SMRK, DMRK. These positions are determined using two optical alignment sensors SS, DS with the method of the invention as described in the claims (however it may alternatively also be done using a single optical alignment sensor). The optical alignment sensors SS, DS each have a fixed and known relative position with respect to the projection optics PO. In this embodiment each optical alignment sensor SMRK, DMRK is dedicated to measuring in one direction only (so determining a position with respect to one axis only). This is done in such a way that the first optical alignment sensor SS, displaced in the direction of the X-axis with respect to the projection optics PO, measures the second position mark DMRK, in a direction complying with the x-axis Xw. The second optical alignment sensor DS, displaced in the direction of the Y-axis with respect to the projection optics PO, measures the first position mark SMRK in a direction complying with the y-axis Yw. The consequence of this is that a rotational error Rz of the chuck 13 around the z-axis is tolerated to some extent, namely by the width of said optical position marks SMRK, DMRK. A substrate (or wafer) 12 typically comprises multiple lanes LN, each comprising a plurality of dies (not shown). All dies are separated from each other by scribe lines, i.e. areas that are reserved for separating the dies by cutting through the scribe lines. Optical alignment marks are preferably places within such scribe lines, such that no unnecessary area is lost.

The next figures further illustrate the method of determining a position of a substrate in accordance with the invention. Fig. 6 shows a modeled intensity profile belonging to the substrate comprising the optical position mark of the invention. Fig. 7

shows a measured intensity profile using the lithography system of the invention. Fig. 8 shows a calculated cross-correlation function between the charts of Figs. 6 and 7. As already discussed the substrate 513 in accordance with the invention comprises an optical position mark SMRK, DMRK for being read-out by an optical recording head 500 for emitting light of predetermined wavelength, preferably red or infra-red light, more in particular of 635 nm light. The optical position mark DMRK, SMRK having a mark width, a mark length and a predetermined known position on the substrate 513. The optical position mark SMRK, DMRK extends along a longitudinal direction X,Y and being arranged for varying a reflection coefficient of the position mark along said longitudinal direction. When the light intensity I is plotted versus the longitudinal position X an intensity profile as shown in Fig. 6 is obtained. The profile of Fig. 6 has been simulated and is based upon an optical position mark as discussed later in this description with reference to Figs. 9, 15-17, and 20. It is not essential that such profile is simulated. It may alternatively be measured on a test substrate comprising such optical position mark. What is important for the invention is that at least an expected intensity profile is obtained before the method is carried out. Subsequently, using the coarse (not-accurate) position the optical alignment sensor is used to scan over the optical position mark and measure an intensity profile. The scan path is chosen intentionally longer than the mark length, such any inaccuracy in the coarse position is taken into account in that it is at least sure that the scan path fully covers the optical position mark. Fig. 7 shows a measured intensity profile. When comparing the profiles of Figs. 6 and 7, a couple of differences are observed. First, the center between the regions having periodically varying reflectivity is shifted. It is exactly this shift which gives the measure for the exact position of the optical position mark with respect to the projection optics. Second, the measured intensity profile is a somewhat deformed version of the measured intensity profile. Third, the scales of both profiles are quite different. Such deformation and scale difference would in the prior art solution cause difficulties in determining a position from the measurement. However, the invention conveniently circumvents such problems by using a very simple position mark combined with a cross-correlation method to determine the shift between the measured intensity profile and the expected (simulated or measured) intensity profile. Fig. 8 shows a possible cross-correlation curve obtained from cross-correlating Figs. 6 and 7. Cross-correlation calculation as such is considered well-known to the person skilled in the art. Various text books are available on this topic. Fig. 8 shows the cross-correlation coefficient CRC as a function of a shift of one said intensity profiles. The figure clearly shows that if Fig. 7 is shifted over a distance of about 0.15 μm that the cross-correlation coefficient is the highest (within the top region TPR), i.e. in that case both intensity profiles resemble each other the most. This figure of 0.15 μm is the correction factor to be added to the earlier-mentioned coarse position to obtain the accurate position of the substrate with respect to the projection optics.

It can be observed that, apart from the clearly visible peak in the curve, there is some periodically varying component super-positioned on this curve. Such varying component may cause an error as it may distort the cross-correlation measurement in that the peak that is slightly shifted with respect to the real shift of the measured curve. An important improvement which leads to an even higher accuracy of the determined position is to first interpolate and filter around the top region TPR of the curve, such that this varying component is at least substantially removed. Subsequently the shift may be determined from the cross-correlation curve.

Fig. 9 schematically shows a substrate comprising an optical position mark according to the invention. This embodiment comprises a first main region 110, a second main region 120 neighboring the first main region 110, and a third main region 130 neighboring the second main region 120. The regions are position such that the optical position mark extends in a longitudinal direction X. At both ends of the optical position mark 140 there is provided end regions 140. The second main region 120 and the end regions 140 are empty regions, i.e. being free of structures, thereby providing a high reflection coefficient. The first main region 110 and the third main region 130 comprise absorbing structures, thereby providing a reflection coefficient that is lower than the reflection coefficient of the empty regions 120,140. It is not essential that the optical position mark has an empty region in the middle. Such region only enhances the optical visibility of the position mark, such that it may be quickly found during experiments. It is also not essential that the end regions 140 are empty. However, such empty regions have a positive impact on shape of the cross-correlation coefficient curve, i.e. the peak will become higher, because the optical position mark can be more easily distinguished from its environment. In this example the first and third regions 110,130 have a length of 100 μm, and the second main region 120 has a length of 50 μm. The end regions 140 in this example have a different length, namely 100 μm, and 50 μm. However, it is not essential that these regions have a different length. The height MH of the optical position mark is preferably less than 40 μm, which is the maximum dimension that fits in a conventional scribe line. Typically, the mark height MH is slightly less than 40 μm in the embodiments discussed in this description. The reason for choosing a value close to the maximum dimension is to obtain the maximum tolerance for position accuracy in that direction, namely +- 20 μm. The total mark length ML is 450 μm.

Within the first main region 110 and the second main region 130 there is a plurality of region pairs 105. Each region pair 105 comprises a first region (or sub-region) 101 having a first reflection coefficient (typically a low coefficient) and a second region

102 having a second reflection coefficient (typically a high coefficient) different from the first reflection coefficient. The first region 101 has a width W that is equal to the width of the second region 102. Consequently, the pitch of each region pair 105 is twice said width W. Depending on the chosen pitch P a predefined number of region pairs fit within the main region 110, 130. As can be observed in Fig. 9, the optical position mark of the invention has a very regular structure, which is advantageous as discussed earlier in this description.

Fig. 9 further shows a third level of segmentation in accordance with the invention, namely that the (black) regions 101 having a low coefficient comprise sub-wavelength structures SWS, wherein sub-wavelength is defined with respect to the wavelength of the light used in the optical reading device for scanning said optical position marks. In the current example the sub-wavelength structures have a sub-wavelength pitch PSW of 200 nm (width is 100nm and spacing is 100nm). In case a DVD read-head is used, the wavelength of the light is typically 635nm (red light). In order to keep the regularity high the segmentation may be vertical, horizontal or dots (both vertical and horizontal segmentation) as illustrated in the figure. Fig. 20 shows a more detailed view of the optical position mark of Fig. 9 for three different scenarios, namely without sub-wavelength structures 100-1, with segmentation in the longitudinal direction 100-2, and with segmentation in the transversal direction 100-3.

Fig. 10 shows another embodiment of the optical position mark MRK1 according to the invention combined with measured intensity profiles of such mark for different mask stacks. The pitch P in this embodiment is 1 μm. Within the first regions 101 there is no further segmentation. Hence, the width of the first regions 101 is 500nm, which is a sub-wavelength dimension in case visible red light is used for reading the intensity profile for the optical position mark. During operational use of a lithography apparatus, such as an E-beam apparatus there are masking layers provided on top of the substrate. Such masking layer includes at least an E-beam resist, but it may comprise more layers. Furthermore, five different wafers WFR1,WFR2,WFR3,WFR4,WFR5 each having different mask layer stacks have been tested to determine the influence of those layers on the position determination method of the invention. In the first wafer WFR1 the substrate does not have any masking layers. In the second to the fifth wafer the substrate comprises a masking layer stack comprising an E-beam resist layer combined with an hard-mask layer (such as spin-on-carbon) having a thickness which increases from the second wafer WFR2 to the fifth wafer WFR5. In between the hard-mask layer and the resist layer there may be a further layer, such as an anti-reflection coating layer and/or an adhesion layer. It is observed from Fig. 10, that the second wafer WFR2 and the third wafer WFR3 have the largest dynamic range in intensity values. From Fig. 10, clearly the main regions and end regions of the optical position mark can be observed, i.e. the light intensity is the lowest for the first main region 110 and the third main region 130, because these regions comprise the structures which at least partially absorb or scatter the incident light.

Fig. 11 shows a zoom view of the profiles of Fig. 10, wherein the zoom view is bounded by the dashed rectangle in Fig. 10. It must be noted that in the experiments the spot size was about 1.5 μm, which is larger than the pitch P. The zoom view shows the light intensity profile in the transition from the end region 140 to the first main region 110. A first observation is that the light intensity drops from a high value (maximum reflection in the end region) to a low value, with a variation super-positioned on it. This variation occurs due to the transitions from structure to empty and visa versa. The period of these variations is 1 μm, because the spot (when scanned over the surface in the longitudinal direction) covers between 1 and 2 structures in an alternating fashion. Furthermore, as the masking layer stack increases (comprising spin-on-carbon) the light intensity drops and the difference between the main regions and the end regions and middle region becomes smaller.

Fig. 12 shows another embodiment of the optical position mark MRK2 according to the invention combined with a zoom view of the measured intensity profiles of such mark for different mask stacks. The pitch P in this embodiment is 2 μm. Within the first regions 101 there is no further segmentation. Within the first regions 101 there is no further segmentation. In this embodiment another phenomenon is observed, namely that there is a minimum in light intensity at each transition. Hence, the period of this variation is 1 μm (half the pitch P). Striking observation is that in the absence of a masking layer stack the difference in light intensity between the end regions 140 and the main regions 110, 130 is quite low.

Fig. 13 shows another embodiment of the optical position mark MRK3 according to the invention combined with a zoom view of the measured intensity profiles of such mark for different mask stacks. The pitch P in this embodiment is 3 μm. Within the first regions 101 there is no further segmentation. Within the first regions 101 there is no further segmentation. There is a minimum in light intensity at each transition. Hence, the period of this variation is 1.5 μm (half the pitch P).

Fig. 14 shows another embodiment of the optical position mark MRK4 according to the invention combined with a zoom view of the measured intensity profiles of such mark for different mask stacks. The pitch P in this embodiment is 4 μm. Within the first regions 101 there is no further segmentation. Within the first regions 101 there is no further segmentation. There is a minimum in light intensity at each transition. Hence, the period of this variation is 2 μm (half the pitch P).

Fig. 15 shows another embodiment of the optical position mark MRK5 comprising sub-wavelength features according to the invention combined with a zoom view of the measured intensity profiles of such mark for different mask stacks. The pitch P in this embodiment is 2 μm. Within the first regions 101 there is longitudinal segmentation. In this embodiment a striking observation can be made. The minima of the light intensity are now observed in the middle of the (segmented) features instead of at the transitions. Moreover, the period of this variation is equal to the pitch P. A further striking observation is that the above is valid for all tested masking layer stacks. Expressed differently, the sub-wavelength features provide for an additional advantage, namely that method of determining the position of the invention (using the optical position marks) is much less sensitive to the masking layer stack that is used on top of the substrate. The pitch of the sub-wavelength features is 200 nm.

Fig. 16 shows another embodiment of the optical position mark MRK6 comprising sub-wavelength features according to the invention combined with a zoom view of the measured intensity profiles of such mark for different mask stacks. The pitch P in this embodiment is 2 μm. Within the first regions 101 there is transversal segmentation. The results for this position mark MRK6 are comparable to those of the fifth position mark MRK5 of Fig. 15. Likewise, this embodiment has the same additional advantage as that of Fig. 15, namely the lower sensitivity to the masking layer stack that is used on top of the substrate. The pitch of the sub-wavelength features is 200 nm.

Fig. 17 shows another embodiment of the optical position mark MRK7 comprising sub-wavelength features according to the invention combined with a zoom view of the measured intensity profiles of such mark for different mask stacks. The pitch P in this embodiment is 2 μm. Within the first regions 101 there is segmentation in both the longitudinal and transversal direction. The results for this position mark MRK7 are slightly worse than those of the fifth and sixth position mark MRK5,MRK6 of Figs. 15 and 16. Likewise, this embodiment has the same additional advantage as that of Figs. 15 and 16, namely the lower sensitivity to the masking layer stack that is used on top of the substrate. An observation is that the curve shape of the intensity profile differs from that of Figs. 15 and 16. Without being bound by any theory, it is assumed that this can be explained by the fact that the double segmentation in Fig. 17 (thus effectively turning the sub-wavelength structures into poles) ensures that light in both polarization directions is absorbed by the structures, whereas in Figs. 15 and 16 the absorption is mainly for one of the polarization directions. The pitch of the sub-wavelength features is 200 nm.

General conclusions from the experiments of Figs. 10 to 17 are.

a) All optical position marks are observable.

b) The amplitudes of the intensity signal decreases for certain masking layer stack thicknesses, and this seems independent of the position mark type.

c) Segmented optical position marks providing sub-wavelength features, provide higher reproducibility.

Fig. 18 shows the reproducibility results of the optical position marks of Figs. 10, 12, 13, 14, 15, 16 and 17 for each optical alignment sensor in the lithography system. Reproducibility is an important performance indicator in position or alignment measurements. For each of the five wafers WFR1,WFR2,WFR3,WFR4,WFR5 (each having the earlier described different masking layer stack) the reproducibility has been measured. The reproducibility was measured as follows. For each wafer the position of the optical position marks were measured at 5 different locations on the wafer, and this measurement was repeated 30 times and this was repeated for both the first optical alignment sensor SS as well as the second optical alignment sensor DS. The bars in Fig. 18 denote the average reproducibility over all 5 locations (or fields). The error bars give the range between the best and worst reproducibility of said 5 locations. What is the most important conclusion from this Fig. 18 is that the segmented marks show a systematically better reproducibility.

Fig. 19 shows accuracy results of the optical position marks of Figs. 10, 12, 13, 14, 15, 16 and 17 for each optical alignment sensor in the lithography system. In the experiments each optical position mark was laid out three in a row. In the accuracy measurements an average offset mark with respect to the outer marks is calculated per wafer per field average. Fig. 19 shows the average (absolute) offset of 5 fields. The results are shown per wafer per mark type. Furthermore, these experiments have been done for both the first optical alignment sensor SS as well as the second optical alignment sensor DS. An important conclusion from Fig. 19 is that the segmented marks show systematically better accuracy.

The invention relates in general to method of determining a position of a substrate in a lithography system, to such substrates as such, and to such lithography system as such. The invention may be applied in various application areas, such as:

- optical position marks on substrates for aligning substrate;
- optical position marks on substrate carriers for aligning substrate carriers;
- optical position marks on chucks for aligning chucks;
- optical position marks on masks;
- optical position marks on auxiliary substrates, such as beam measurement substrates in E-beam machines.

It is to be understood that the above description is included to illustrate the operation of the preferred embodiments and is not meant to limit the scope of the invention. From the above discussion, many variations will be apparent to one skilled in the art that would yet be encompassed by the spirit and scope of the present invention.

In addition, it is to be understood that, when in the above description and in the appended claims the phrase “a plurality of times” is used, this is meant to encompass two times or more.

The invention may also be defined in accordance with the following clauses.

Clause 1. A substrate (12,513) comprising an optical position mark (100) for being read-out by an optical recording head (500) for emitting light of a predetermined wavelength, preferably red or infra-red light, more in particular of 635 nm light, the optical position mark (100) having a mark height (MH), a mark length (ML) and a predetermined known position on the substrate (12,513), the optical position mark (100) extending along a longitudinal direction (x) and being arranged for varying a reflection coefficient of the position mark (100) along said longitudinal direction (x), wherein the optical position mark (100) comprises:

- a first region (101) having a first reflection coefficient and a first width (W);
- a second region (102) neighboring the first region (101) and forming a first region pair (105), the second region (102) having a second reflection coefficient and a second width (W), and the second reflection coefficient being different from the first reflection coefficient, wherein the first region (101) comprises sub-wavelength structures (SWS) in comparison with a wavelength of the predetermined wavelength light.

Clause 2. The substrate (12,513) as claimed in clause 1, wherein the sub-wavelength structures (SWS) comprise a plurality of regular stripe-shaped segments extending in a further direction (y) perpendicular to the longitudinal direction (x), wherein each regular segment is formed by a first sub-region and a second sub-region.

Clause 3. The substrate (12,513) as claimed in clause 1, wherein the sub-wavelength structures (SWS) comprise a plurality of regular stripe-shaped segments extending in the longitudinal direction (x), wherein each regular stripe-shaped segment is formed by a first sub-region and a second sub-region.

Clause 4. The substrate (12,513) as claimed in any one of the preceding claims, further comprising a first regional pair (105) and at least a second region pair (105), wherein said second region pair (105) is substantially equal to the said first region pair

(105).

Clause 5. The substrate (12,513) as claimed in any one of the preceding claims, wherein the first width (W) and the second width (W) are in a range between 1 μm and 2 μm.

Clause 6. The substrate (12,513) as claimed in any one of the preceding claims, wherein the mark length (ML) is at least 100 μm.

Clause 7. The substrate (12,513) as claimed in any one of the preceding claims, wherein the sub-wavelength structures (SWS) provide for the first reflection coefficient being lower than the second reflection coefficient.

Clause 8. The substrate (12,513) as claimed in any one of clauses 4 to 7, in as far as directly or indirectly dependent on clause 4, wherein the first region pair (105) and said second region pair (105) form a first main region (110), and further comprising a second main region (120) neighboring the first main region (110), wherein the second main region (120) is substantially free of structures.

Clause 9. The substrate (12,513) as claimed in clause 8, further comprising a third main region (130) neighboring the second main region (120), wherein the second main region (120) is embedded between the first main region (110) and the third main region (130) when viewed in the longitudinal direction (x).

Clause 10. The substrate (12,513) as claimed in clause 9, wherein the third main region (130) is build up in a similar manner as the first region (101) comprising sub-wavelength structures.

Clause 11 The substrate (12,513) as claimed in clause 10, wherein the first main region (110) and the third main region (130) are substantially identical.

Clause 12. The substrate (12,513) as claimed in any one of clauses 9 to 11, further comprising a first end region (140) located at a first end of the optical position mark (100) neighboring the first main region (110), the first end region (140) being substantially free of structures.

Clause 13. The substrate (12,513) as claimed in any one of clauses 9 to 12, further comprising a second end region (140) located at a second end of the optical position mark (100) neighboring the third main region (130), the second end region (140) being substantially free of structures.

Clause 14. The substrate (12,513) as claimed in any one of the preceding claims, wherein the mark height is a plurality of times the wavelength of the red or infra-red light.

Clause 15. A lithography system for processing a substrate according to any one of the preceding claims, the system comprising an optical alignment sensor (SS,500) mounted to the system such that it has a substantially constant distance from a substrate exposure means (1,PO), the optical alignment sensor (SS,500) being configured for emitting a light beam (511) to the substrate (12,513) and for measuring an intensity profile of a zero-th order reflected light beam (518),

wherein the lithography system is configured for carrying out the method as claimed in any one of clauses 21 to 27.

Clause 16. The lithography system as claimed in clause 15, the system further comprising:

- a further optical alignment sensor (DS,500) mounted to the system such that it has a further substantially constant distance from the substrate exposure means (1,PO), the optical alignment sensor (DS,500) being configured for emitting a further light beam (511) to the substrate (12,513) and for measuring an intensity profile of a zero-th order reflected light beam (518), the lithography system being configured for allowing said optical alignment sensor (SS,500) scanning in a first direction (y), and the lithography system being configured for allowing said further optical alignment sensor (DS,500) scanning in a second direction (x) orthogonal to said first direction (y).

Clause 17. The lithography system as claimed in clause 16, wherein the first direction (y) coincides with a first movement direction (L) of the substrate (12,513) in operational use of the lithography system, and the second direction (x) coincides with a second movement direction (S) of the substrate (12,513) in operational use of the lithography system.

Clause 18. The lithography system as claimed in any one of clauses 15 to 17, further comprising a driver stage for moving and positioning said substrate carrier (13) with respect to the substrate exposure system (1).

Clause 19. The lithography system as claimed in any one of clauses 15 to 18, wherein the substrate exposure means (1,PO) comprises an optical column (PO) adapted for projecting one or more exposure beams on the substrate (12,513), wherein said alignment sensors (SS,DS) are mounted to the optical column (PO).

Clause 20. The lithography system as claimed in clause 19, wherein the optical column (PO) is configured for projecting a multitude of charged particle exposure beams, such as electron beams, on the substrate (12,513).

Clause 21. A method of determining a position of a substrate (12,513) in a lithography system (1), the system (1) comprising an optical alignment sensor (SS,DS) for emitting a light beam (511) to the substrate (12,513) and for measuring an intensity profile of a zero-th order reflected light beam (518), the method comprising:

- providing a substrate (12,513) comprising an optical position mark (100) having a mark width (MW), a mark length (ML) and a predetermined known position on the substrate (12,513), the optical position mark (100) extending along a longitudinal direction (x) and being arranged for varying a reflection coefficient of the position mark (100) along said longitudinal direction (x);
- moving the substrate (12,513) such that the optical position mark (100) is substantially near the optical alignment sensor (SS,DS) in accordance with an estimated position of the optical position mark (100) with regards to the optical alignment sensor (SS,DS);
- scanning the optical position mark (100) along a scan path in the longitudinal direction with the optical alignment sensor (100) to obtain a measured intensity profile having a scan length, wherein the scan length is longer than the mark length (ML);
- comparing the measured intensity profile with an expected intensity profile associated with the optical position mark (100) to determine a difference (x) between an actual position of the optical position mark (100) and the estimated position, and
- determining the actual position of the position mark from the scan path and said difference.

Clause 22. The method as claimed in clause 21, wherein the step of comparing of the measured intensity profile with the expected intensity profile comprises:

- calculating a cross-correlation function (CRC) between said profiles, and
- determining a location of a maximum (TPR) in said cross-correlation function (CRC), wherein said location is indicative for said difference.

Clause 23. The method of clause 21 or 22, wherein, in the step of providing the substrate (12,513), the substrate (12,513) comprises a further optical position mark (100) having a further mark width (MW), a further mark length (ML) and a further predetermined known position on the substrate (12,513), the further optical position mark (100) extending along a further longitudinal direction (y) and being arranged for varying a further reflection coefficient of the further position mark (100) along said further longitudinal direction (y), wherein said further longitudinal direction (y) is orthogonal to said longitudinal direction (x), wherein the optical position mark (100) and the further optical position mark (100) form a position mark couple the method further comprising, after the step of scanning the optical position mark, steps of:

- moving the substrate (12,513) such that the further optical position mark (100) is substantially near the optical alignment sensor (SS,DS) in accordance with a further estimated position of the further optical position mark (100) with regards to the optical alignment sensor (SS,DS);
- scanning the further optical position mark (100) along a further scan path in the further longitudinal direction with the optical alignment sensor (SS,DS) to obtain a further measured intensity profile having a further scan length, wherein the further scan length is longer than the further mark length (ML);
- comparing the further measured intensity profile with a further expected intensity profile associated with the further optical position mark (100) to determine a further difference between a further actual position of the further optical position mark (100) and the further estimated position, and
- determining the further actual position of the further position mark from the further scan path and said further difference.

Clause 24. The method as claimed in clause 23, wherein the step of comparing of the further measured intensity profile with the further expected intensity profile comprises:

- calculating a further cross-correlation function between said profiles, and
- determining a further location of a maximum in said further cross-correlation function, wherein said further location is indicative for said difference.

Clause 25. The method as claimed in 23 or 24, wherein the lithography system comprises a further optical alignment sensor (DS) for emitting a further light beam to the substrate (12,513) and for measuring an intensity profile of a zero-th order reflected light beam, the lithography system being configured for allowing said optical alignment sensor scanning only in a first direction (y), and the lithography system being configured for allowing said further optical alignment sensor (DS) scanning only in a second direction (x) orthogonal to said first direction (y),

wherein, in the step of providing the substrate (12,513) the longitudinal direction (x) of the optical position mark (100) coincides with the first direction (y) and the further longitudinal direction (x) of the further optical position mark (100) coincides with the second direction (x),

wherein, in the respective steps of scanning, the optical alignment sensor (DS) is used for scanning the optical position mark (100) and the further optical alignment sensor (DS) is used for scanning the further optical position mark (100).

Clause 26. The method as claimed in clause 25, wherein the first direction (y) coincides with a first movement direction (L) of the substrate (12,513) in operational use of the lithography system, and the second direction (x) coincides with a second movement direction (S) of the substrate (12,513) in operational use of the lithography system.

Clause 27. The method as claimed in any one of clauses 21 to 26, wherein, in the step of providing the substrate (12,513), the substrate (12,513) comprises a second optical position mark couple being located at a different location on the substrate (12,513), wherein the second optical position mark couple is similar to a first optical position mark couple, and wherein the method is repeated for said second optical position mark couple.

Clause 28. The lithography system as claimed in any one of clauses 15 to 20, further comprising a substrate carrier (13) for receiving said substrate (12,513), wherein the substrate carrier (13) is movable with respect to the substrate exposure means (1,PO) for allowing exposure of different parts of said substrate (12,513).

CONCLUSIES

1. Substraat (12,513) omvattend een optische positiemarkering (100), waarbij de optische positiemarkering (100) een markeringshoogte (MH), een markeringslengte (ML) en een vooraf bepaalde bekende positie op het substraat (12,513) heeft, waarbij de optische positiemarkering (100) zich uitstrekt langs een lengterichting (x) en is gerangschikt voor het langs de lengterichting (x) variëren van een reflectiecoëfficiënt van de positiemarkering (100), waarbij de optische positiemarkering (100) omvat:

- een eerste gebied (101) met een eerste reflectiecoëfficiënt en een eerste breedte (W);
- een tweede gebied (102) naburig aan het eerste gebied (101) en een eerste gebiedspaar (105) vormend, waarbij het tweede gebied (102) een tweede reflectiecoëfficiënt heeft en een tweede breedte (W), en de tweede reflectiecoëfficiënt verschillend is van de eerste reflectiecoëfficiënt, waarbij het eerste gebied (101) subgolflengte-structuren (SWS) omvat in vergelijking met een golflengte van het licht met vooraf bepaalde golflengte en het tweede gebied (102) vrij is van subgolflengte-structuren (SWS).

2. Substraat (12,513) volgens conclusie 1, waarbij de subgolflengte-structuren (SWS) een veelvoud aan regelmatige streepvormige segmenten omvat die zich in een verdere richting (y) loodrecht op de lengterichting (x) uitstrekken, waarbij elke regelmatig segment gevormd is door een eerste subgebied en een tweede subgebied.

3. Substraat (12,513) volgens conclusie 1, waarbij de subgolflengte-structuren (SWS) een veelvoud aan regelmatige streepvormige segmenten omvat die zich in de lengterichting (x) uitstrekken, waarbij elk regelmatig streepvormig segment gevormd is door een eerste subgebied en een tweede subgebied.

4. Substraat (12,513) volgens een der voorgaande conclusies, verder omvattend een eerste gebiedspaar (105) en ten minste een tweede gebiedspaar (105), waarbij het tweede gebiedspaar (105) in hoofdzaak gelijk is

aan het eerste gebiedspaar (105).

5. Substraat (12,513) volgens een der voorgaande conclusies, waarbij de eerste breedte (W) en de tweede breedte (W) in een bereik zijn van tussen 1 µm en 2 µm.

6. Substraat (12,513) volgens een der voorgaande conclusies, waarbij de lengte van de markering (ML) ten minste 100 µm is.

7. Substraat (12,513) volgens een der voorgaande conclusies, waarbij de subgolflengte-structuren (SWS) er in voorzien dat de eerste reflectiecoëfficiënt lager is dan de tweede reflectiecoëfficiënt.

8. Substraat (12,513) volgens een der conclusies 4-7, voor zover direct of indirect afhankelijk van conclusie 4, waarbij het eerste gebiedspaar (105) en het tweede gebiedspaar (105) een eerste hoofdgebied (110) vormen, en verder omvattend een tweede hoofdgebied (120) naburig aan het eerste hoofdgebied (110), waarbij het tweede hoofdgebied (120) in hoofdzaak vrij is van structuren.

9. Substraat (12,513) volgens conclusie 8, verder omvattend een derde hoofdgebied (130) naburig aan het tweede hoofdgebied (120), waarbij het tweede hoofdgebied (120) is ingebed tussen het eerste hoofdgebied (110) en het derde hoofdgebied (130) wanneer bezien in de lengterichting (x).

10. Substraat (12,513) volgens conclusie 9, waarbij het derde hoofdgebied (130) op eenzelfde wijze is opgebouwd als het eerste gebied (101) omvattend subgolflengte-structuren.

11. Substraat (12,513) volgens conclusie 10, waarbij het eerste hoofdgebied (110) en het derde hoofdgebied (130) in hoofdzaak identiek zijn.

12. Substraat (12,513) volgens een der conclusies 9-11, verder omvattend een eerste eindgebied (140) geplaatst aan een eerste einde van de optische positiemarkering (100) naburig aan het eerste hoofdgebied (110), waarbij het eerste eindgebied (140) in hoofdzaak vrij is van structuren.

13. Substraat (12,513) volgens een der conclusies 9-12, verder omvattend een tweede eindgebied (140) geplaatst aan een tweede eind van de optische positiemarkering (100) naburig aan het derde hoofdgebied (130), waarbij het tweede eindgebied (140) in hoofdzaak vrij is van structuren.

14. Substraat (12,513) volgens een der voorgaande conclusies, waarbij de markeringshoogte een veelvoud is van de golflengte van het rode of infrarood licht.

15. Lithografiesysteem voor het verwerken van een substraat volgens een der voorgaande conclusies, waarbij het systeem een optische uitlijnsensor (SS,500) omvat zodanig op het systeem bevestigd dat het een in hoofdzaak constante afstand heeft van een substraat blootstellingsmiddel (1,PO), waarbij de optische uitlijnsensor (SS,500) is ingericht voor het uitzenden van een lichtstraal (511) naar het substraat (12,513) en voor het meten van een intensiteitprofiel van een nulde orde gereflecteerde lichtstraal (518),

waarbij het lithografiesysteem is ingericht voor het uitvoeren van de werkwijze volgens een der conclusies 21-27.

16. Lithografiesysteem volgens conclusie 15, waarbij het systeem verder omvat:

- een verdere optische uitlijnsensor (DS,500) zodanig op het systeem bevestigd dat het een verdere in hoofdzaak constante afstand heeft van het substraat blootstellingsmiddel (1,PO), waarbij de optische uitlijnsensor (DS,500) is ingericht voor het uitzenden van een verdere lichtstraal (511) naar het substraat (12,513) en voor het meten van een intensiteitprofiel van een nulde orde gereflecteerde lichtstraal (518), waarbij het lithografiesysteem is ingericht om het scannen van de optische uitlijnsensor (SS,500) in een eerste richting (y) mogelijk te maken, en het lithografiesysteem is ingericht om het scannen van de verdere optische uitlijnsensor (DS,500) in een tweede richting (x) orthogonaal aan de eerste richting (y) mogelijk te maken.

17. Lithografiesysteem volgens conclusie 16, waarbij de eerste richting (y) samenvalt met een eerste bewegingsrichting (L) van het substraat (12,513) bij operationeel gebruik van het lithografiesysteem, en de tweede richting (x) samenvalt met een tweede bewegingsrichting (S) van het substraat (12,513) bij operationeel gebruik van het lithografiesysteem.

18. Lithografiesysteem volgens een der conclusies 15-17, verder omvattend een aandrijfplatform voor het bewegen en positioneren van de substraatdrager (13) ten opzichte van het substraat blootstellingssysteem (1).

19. Lithografiesysteem volgens een der conclusies 15-18, waarbij het substraat blootstellingsmiddel (1,PO) een optische kolom (PO) omvat ingericht voor het projecteren van een of meer blootstellingsstralen op het substraat (12,513), waarbij de uitlijnsensoren (SS,DS) zijn bevestigd aan de optische kolom (PO).

20. Lithografiesysteem volgens conclusie 19, waarbij de optische kolom (PO) is ingericht voor het projecteren van een meervoud aan geladen deeltjes blootstellingsstralen, zoals elektronenstralen, op het substraat (12,513).

21. Werkwijze omvattende:

- het verschaffen van een substraat (12,513) omvattend een optische positiemarkering (100) met een markeringsbreedte (MW), een markeringslengte (ML) en een vooraf bepaalde bekende positie op het substraat (12,513), waarbij de optische positiemarkering (100) zich uitstrekt langs een lengterichting (x) en is ingericht voor het variëren van een reflectiecoëfficiënt van de positiemarkering (100) langs de lengterichting (x);

- het bewegen van het substraat (12,513) zodanig dat de optische positiemarkering (100) in hoofdzaak nabij een optische uitlijnsensor (SS,DS) is in overeenstemming met een geschatte positie van de optische positiemarkering (100) ten opzichte van de optische uitlijnsensor (SS,DS);

- het scannen van de optische positiemarkering (100) langs een scanpad in de lengterichting met de optische uitlijnsensor (100) om een gemeten intensiteitprofiel te verkrijgen met een scanlengte, waarbij de scanlengte langer is dan de markeringslengte (ML);

- het vergelijken van het gemeten intensiteitprofiel (fig. 7) met een verwacht intensiteitprofiel (fig. 6) geassocieerd met de optische positiemarkering (100) om een verschil (x) te bepalen tussen een werkelijke positie van de optische positiemarkering (100) en de geschatte positie, en

- het bepalen van de werkelijke positie van de positiemarkering uit het scanpad en het verschil.

22. Werkwijze volgens conclusie 21, waarbij de stap van het vergelijken van het gemeten intensiteitprofiel met het verwachte intensiteitprofiel omvat:

- het berekenen van een kruiscorrelatie functie (CRC) tussen de profielen (Fig.6;Fig.7), en
- het bepalen van een locatie van een maximum (TPR) in de kruiscorrelatie functie (CRC), waarbij de locatie indicatief is voor het verschil.

23. Werkwijze volgens conclusie 21 of 22, waarin, in de stap van het verschaffen van het substraat (12, 513), het substraat (12,513) een verdere optische positiemarkering (100) omvat met een verdere markeringsbreedte (MW), een verdere markeringslengte (ML) en een verdere vooraf bepaalde bekende positie op het substraat (12,513), waarbij de verdere optische positiemarkering (100) zich uitstrekt langs een verdere lengterichting (y) en is ingericht voor het variëren van een verdere reflectiecoëfficiënt van de verdere positiemarkering (100) langs de verdere lengterichting (y), waarbij de verdere lengterichting (y) orthogonaal is aan de lengterichting (x), waarbij de optische positiemarkering (100) en de verdere optische positiemarkering (100) een positiemarkering-paar vormen, waarbij de werkwijze verder omvat, na de stap van het scannen van de optische positiemarkering, de stappen van:

- het bewegen van het substraat (12,513) zodanig dat de verdere optische positiemarkering (100) in hoofdzaak nabij de optische uitlijnsensor (SS,DS) is in overeenstemming met een verdere geschatte positie van de verdere optische positiemarkering (100) ten opzichte van de optische uitlijnsensor (SS,DS);
- het scannen van de verdere optische positiemarkering (100) langs een verder scanpad in de verdere lengterichting met de optische uitlijnsensor (SS,DS) om een verder gemeten intensiteitprofiel met een verdere scanlengte te verkrijgen, waarbij de verdere scanlengte langer is dan de verdere markeringslengte (ML);
- het vergelijken van het verdere gemeten intensiteitprofiel met een verder verwacht intensiteitprofiel geassocieerd met de verdere optische positiemarkering (100) om een verder verschil te bepalen tussen een verdere werkelijke positie van de verdere optische positiemarkering (100) en de verdere geschatte positie, en
- het bepalen van de verdere werkelijke positie van de verdere positiemarkering uit het verdere scanpad en het verdere verschil.

24. Werkwijze volgens conclusie 23, waarbij de stap van het vergelijken van het verdere gemeten intensiteitprofiel met het verdere verwachte intensiteitprofiel omvat:

- het berekenen van een verdere kruiscorrelatie functie tussen de profielen, en
- het bepalen van een verdere locatie van een maximum in de verdere kruiscorrelatie functie, waarbij de verdere locatie indicatief is voor het verschil.

25. Werkwijze volgens conclusie 23 of 24, waarbij het lithografiesysteem een verdere optische uitlijnsensor (DS) omvat voor het uitzenden van een verdere lichtstraal naar het substraat (12,513) en voor het meten van een intensiteitprofiel van een nulde orde gereflecteerde lichtstraal, waarbij het lithografiesysteem is ingericht om scannen van de optische uitlijnsensor in slechts een eerste richting (y) toe te staan, en waarbij het lithografiesysteem is ingericht om scannen van de verdere optische uitlijnsensor (DS) slechts in een tweede richting (x) orthogonaal aan de eerste richting (y) toe te staan,

waarbij, in de stap van het verschaffen van het substraat (12,513), de lengterichting (x) van de optische positiemarkering (100) samenvalt met de eerste richting (y), en de verdere lengterichting (x) van de verdere optische positiemarkering (100) samenvalt met de tweede richting (x),

waarin, in de respectievelijke stappen van het scannen, de optische uitlijnsensor (DS) wordt gebruikt voor het scannen van de optische positiemarkering (100) en de verdere optische uitlijnsensor wordt gebruikt voor het scannen van de verdere positiemarkering (100).

26. Werkwijze volgens conclusie 25, waarbij de eerste richting (y) samenvalt met een eerste bewegingsrichting (L) van het substraat (12,513) bij operationeel gebruik van het lithografiesysteem, en de tweede richting (x) samenvalt met een tweede bewegingsrichting (S) van het substraat (12,513) bij operationeel gebruik van het lithografiesysteem.

27. Werkwijze volgens een der conclusies 21-26, waarin, in de stap van het verschaffen van het substraat (12,513), het substraat (12, 513) een tweede optisch positiemarkering-paar omvat dat geplaatst is op een

verschillende locatie op het substraat (12,513), waarbij het tweede optisch positiemarkering-paar gelijkend is aan het eerste optische positiemarkering-paar, en waarbij de werkwijze wordt herhaald voor het tweede optisch positiemarkering-paar.

28. Lithografiesysteem volgens een der conclusies 15-20, verder omvattende een substraatdrager (13) voor het ontvangen van het substraat (12,513), waarbij de substraatdrager (13) beweegbaar is ten opzichte van de substraat blootstellingsmiddelen (1,PO) om blootstelling van verschillende delen van het substraat (12,513) mogelijk te maken.

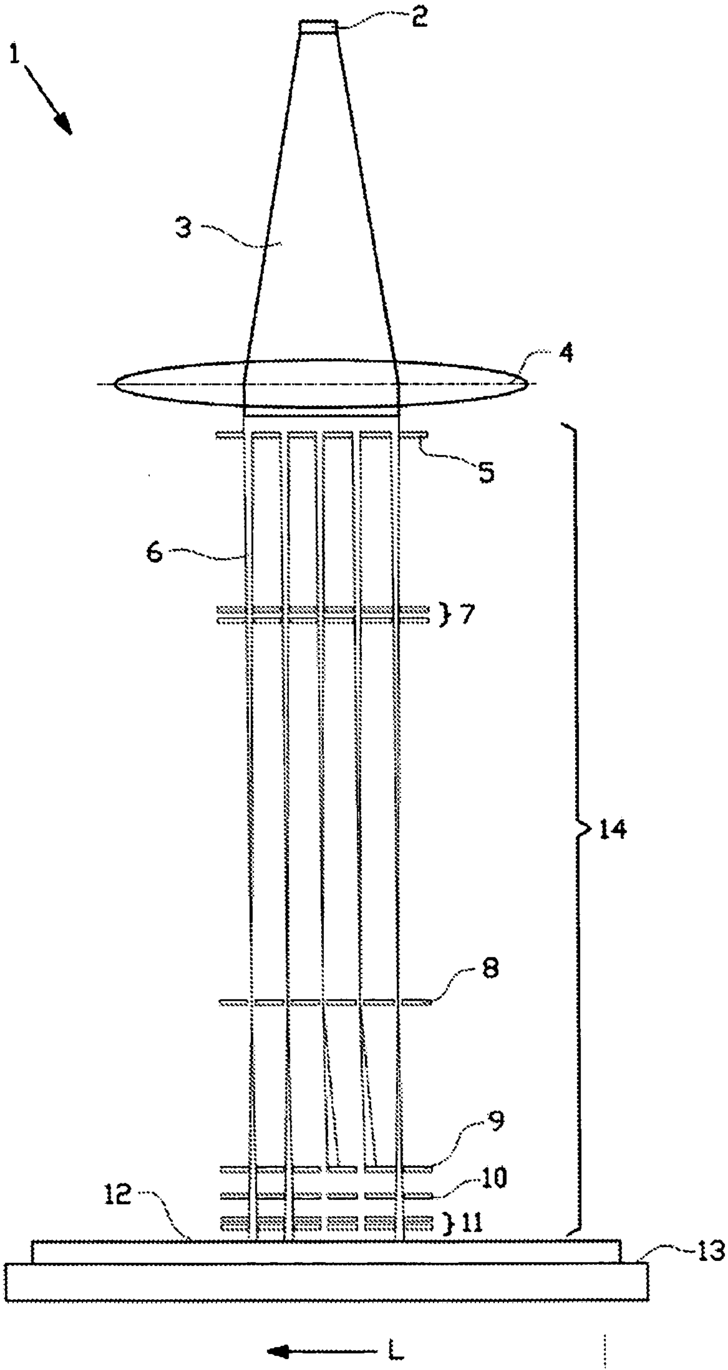


FIG. 1

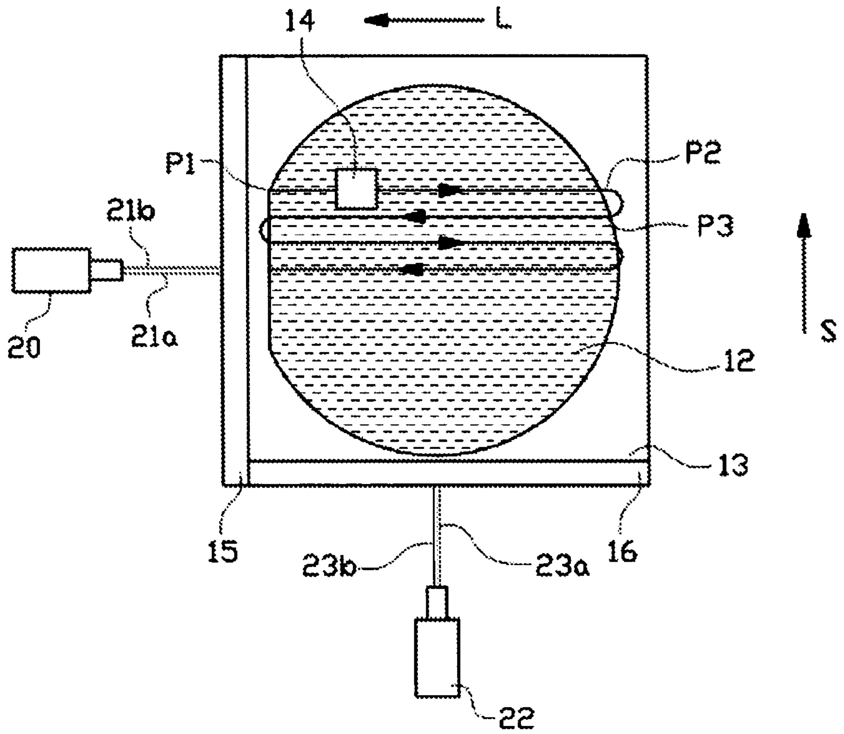


FIG. 2

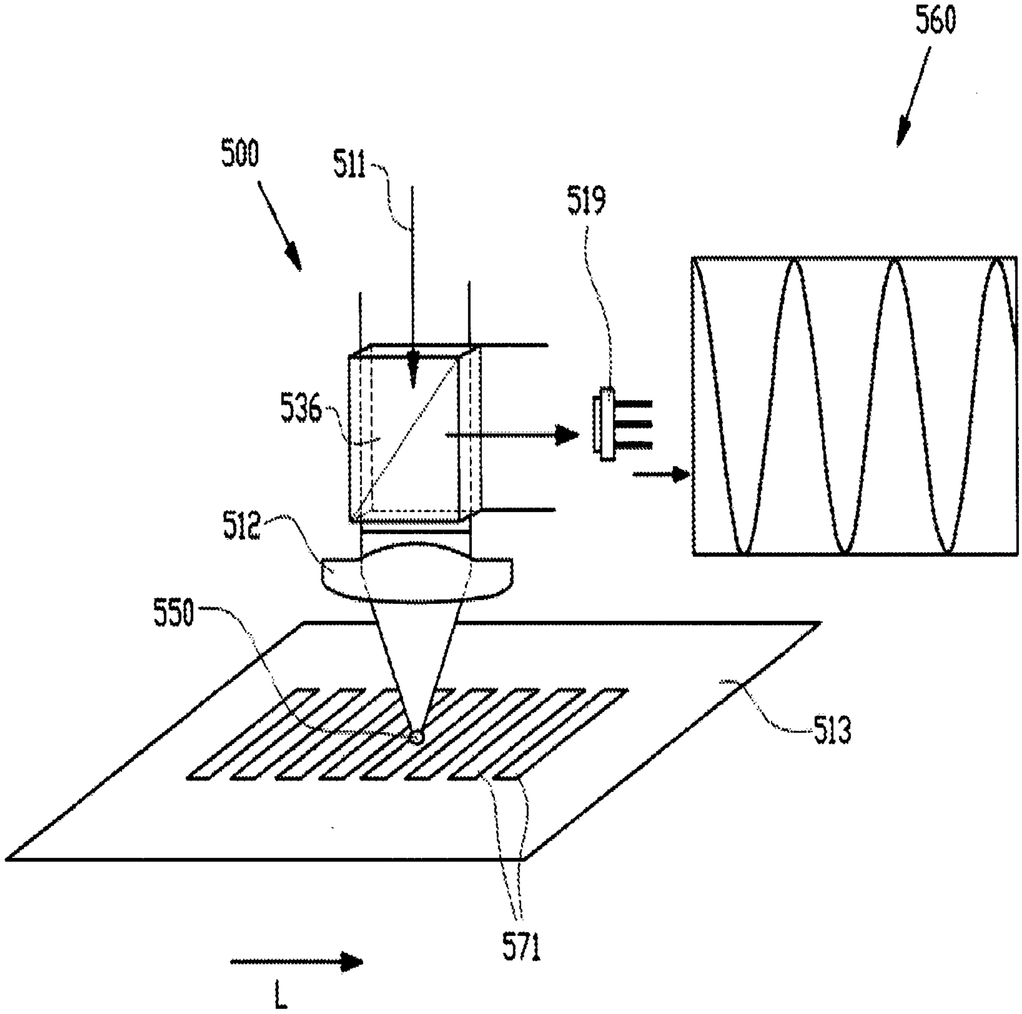


FIG. 3

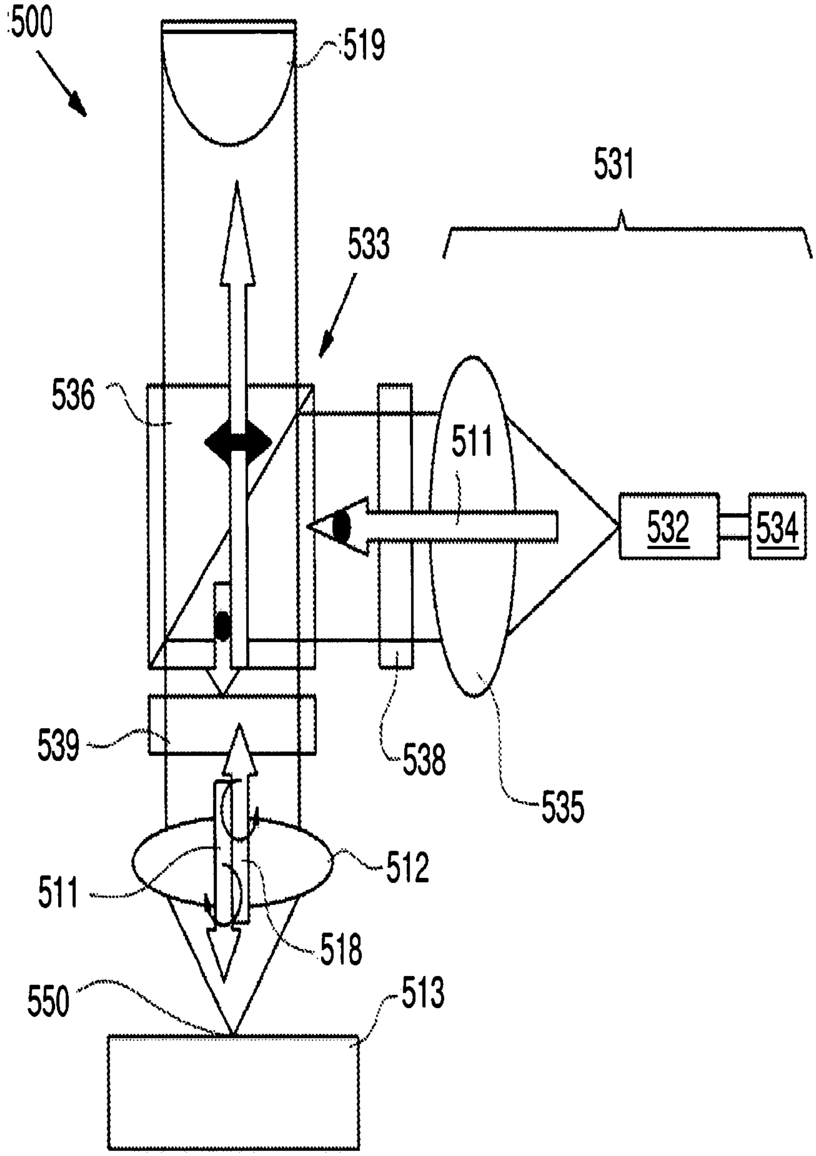


FIG. 4

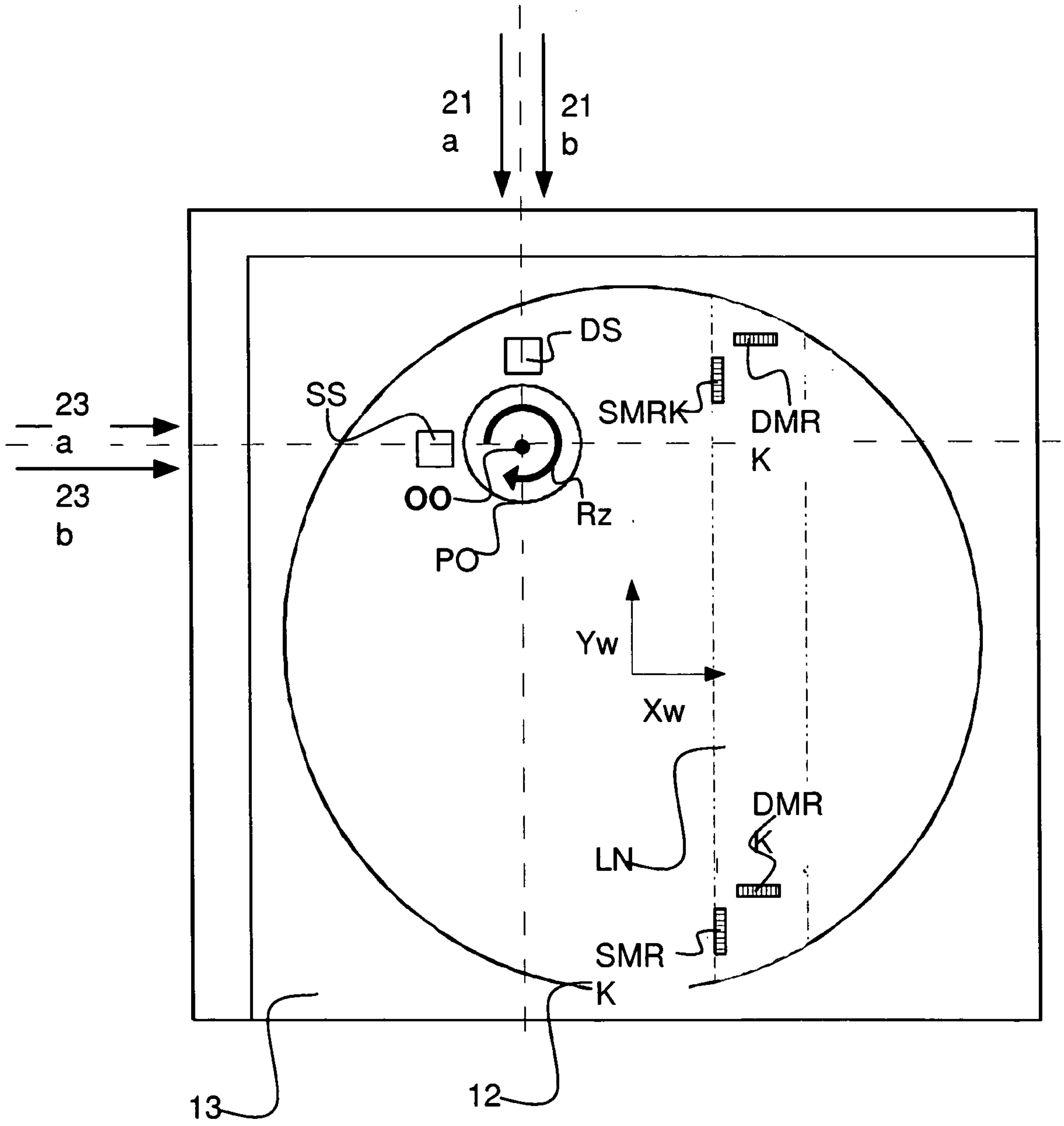
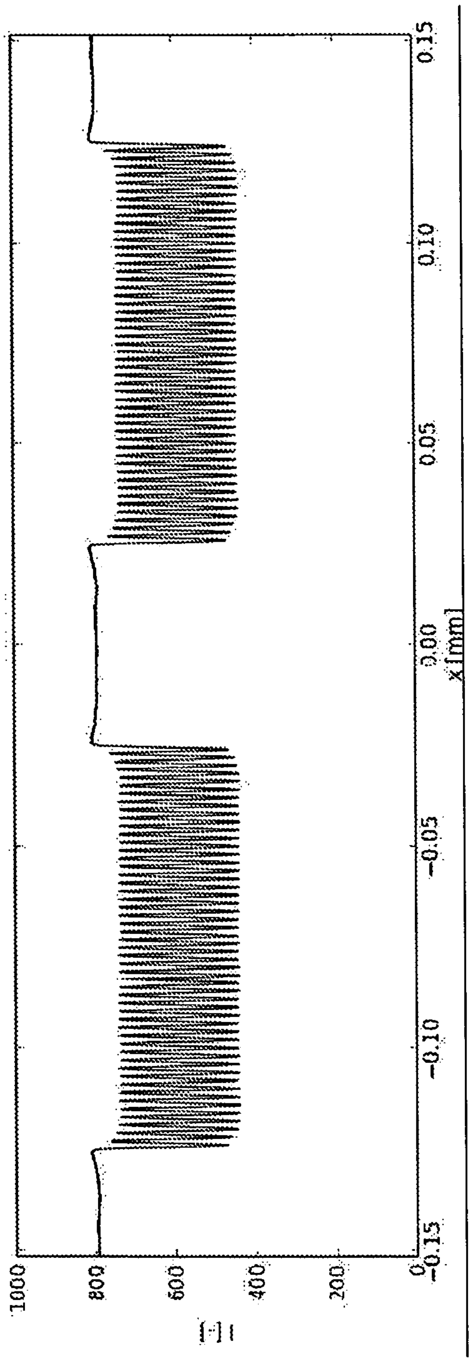
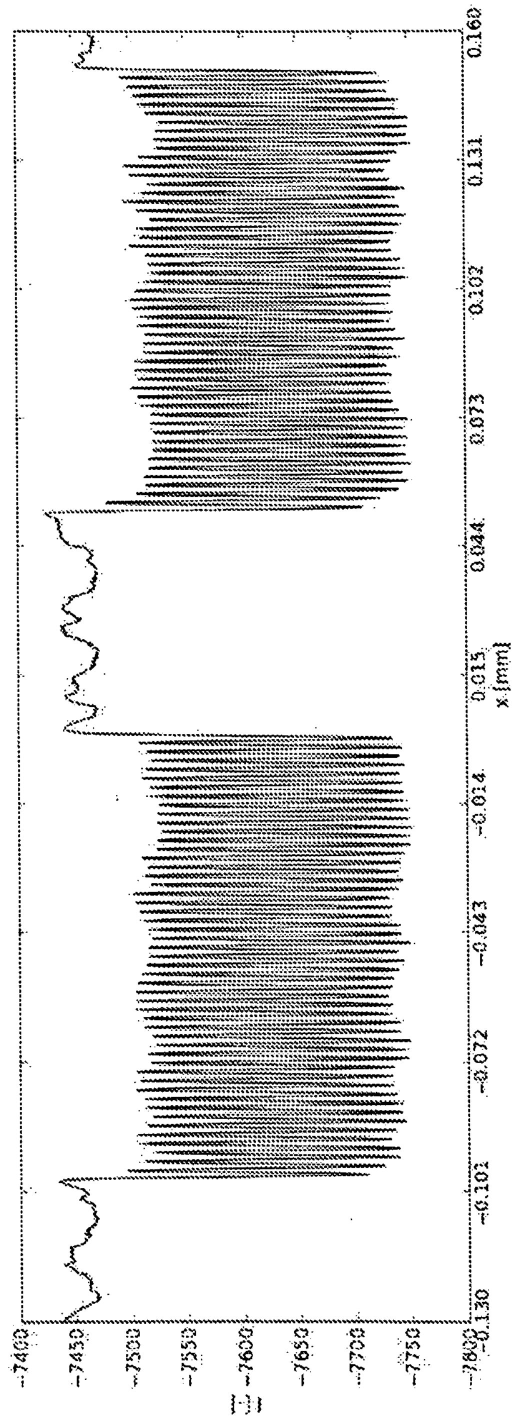


FIG. 5



1000
800
600
400
200
0
[-]
−0.15
−0.10
−0.05
0.00
0.05
0.10
0.15
x [mm]

FIG. 6



-7400
-7450
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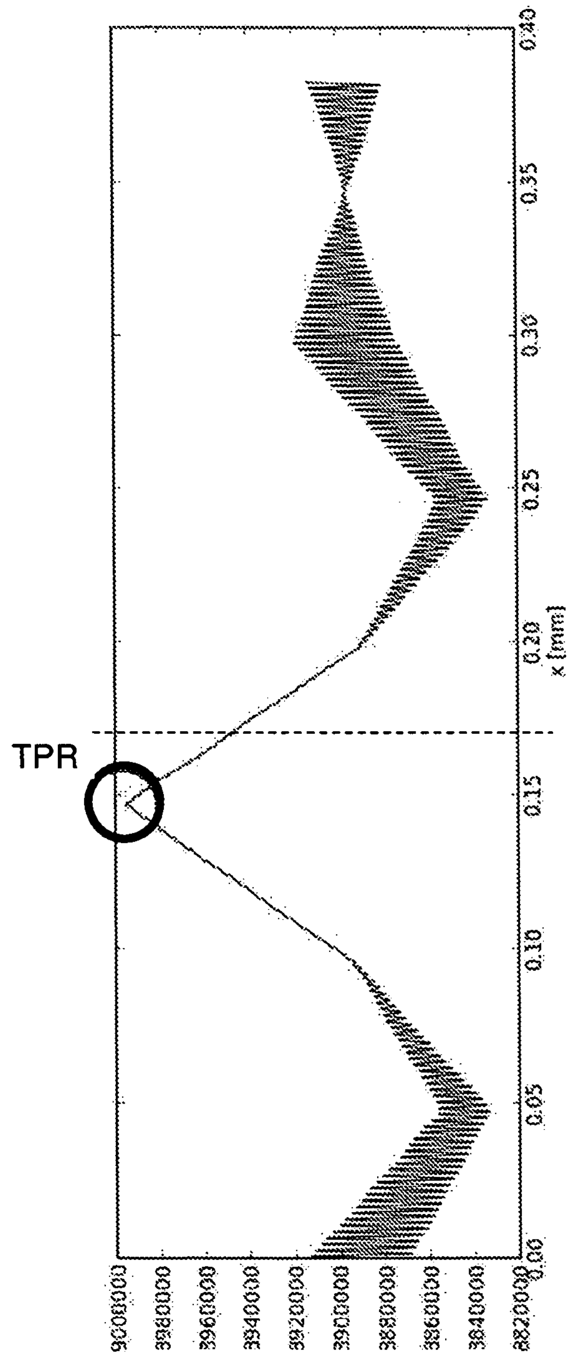
−0.014
0.015
0.044
0.073
0.102
0.131
0.160
x [mm]

FIG. 7


TPR
x [mm]
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0.05
0.10
0.15
0.20
0.25
0.30
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0.40
3980000
3960000
3940000
3920000
3900000
3880000
3860000
3840000
3820000

CRC

FIG. 8

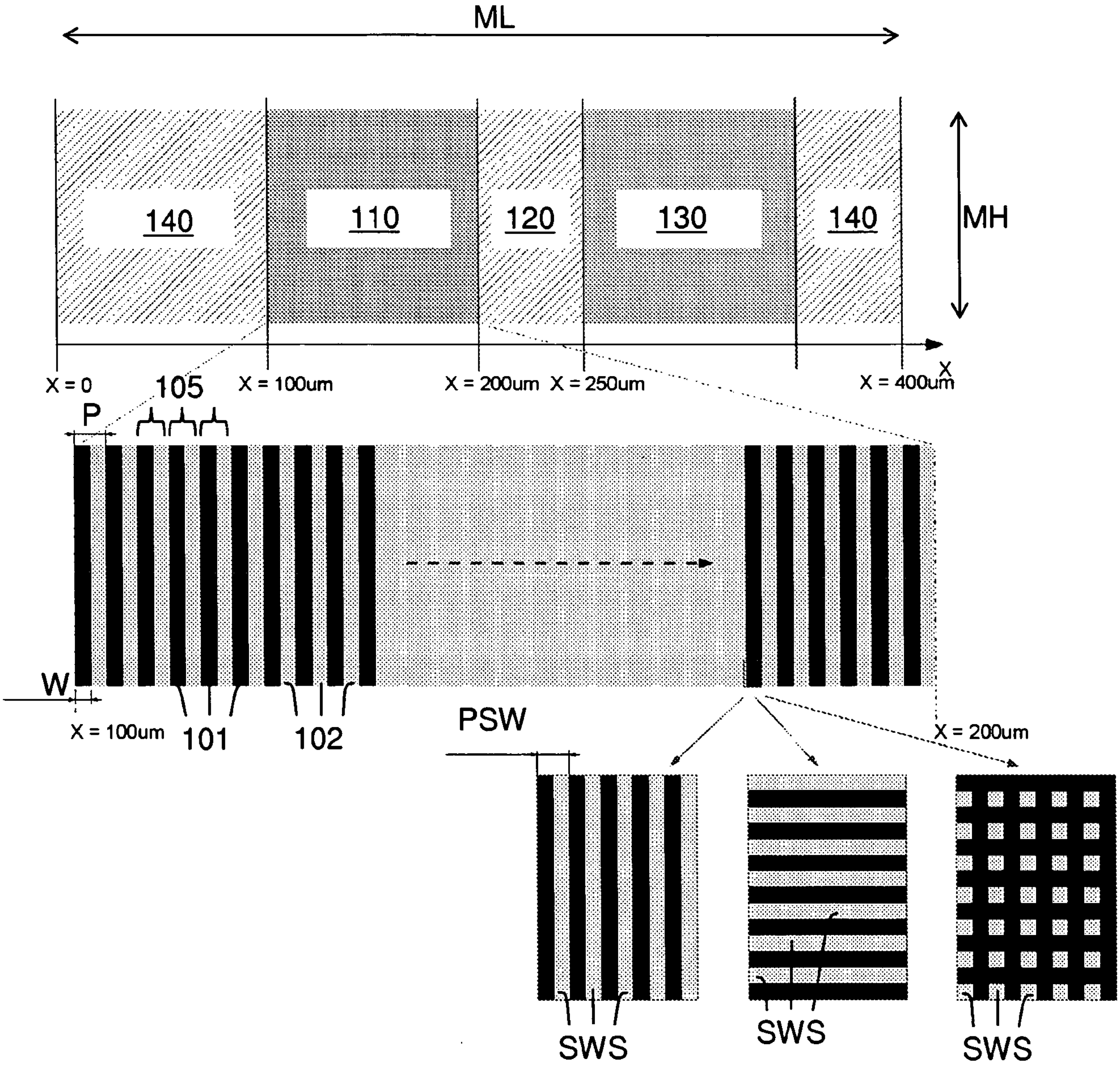

ML
140
110
120
130
140
MH
X = 0
105
X = 100um
X = 200um
X = 250um
X = 400um
X
P
W
X = 100um
101
102
PSW
X = 200um
SWS
SWS
SWS

FIG. 9

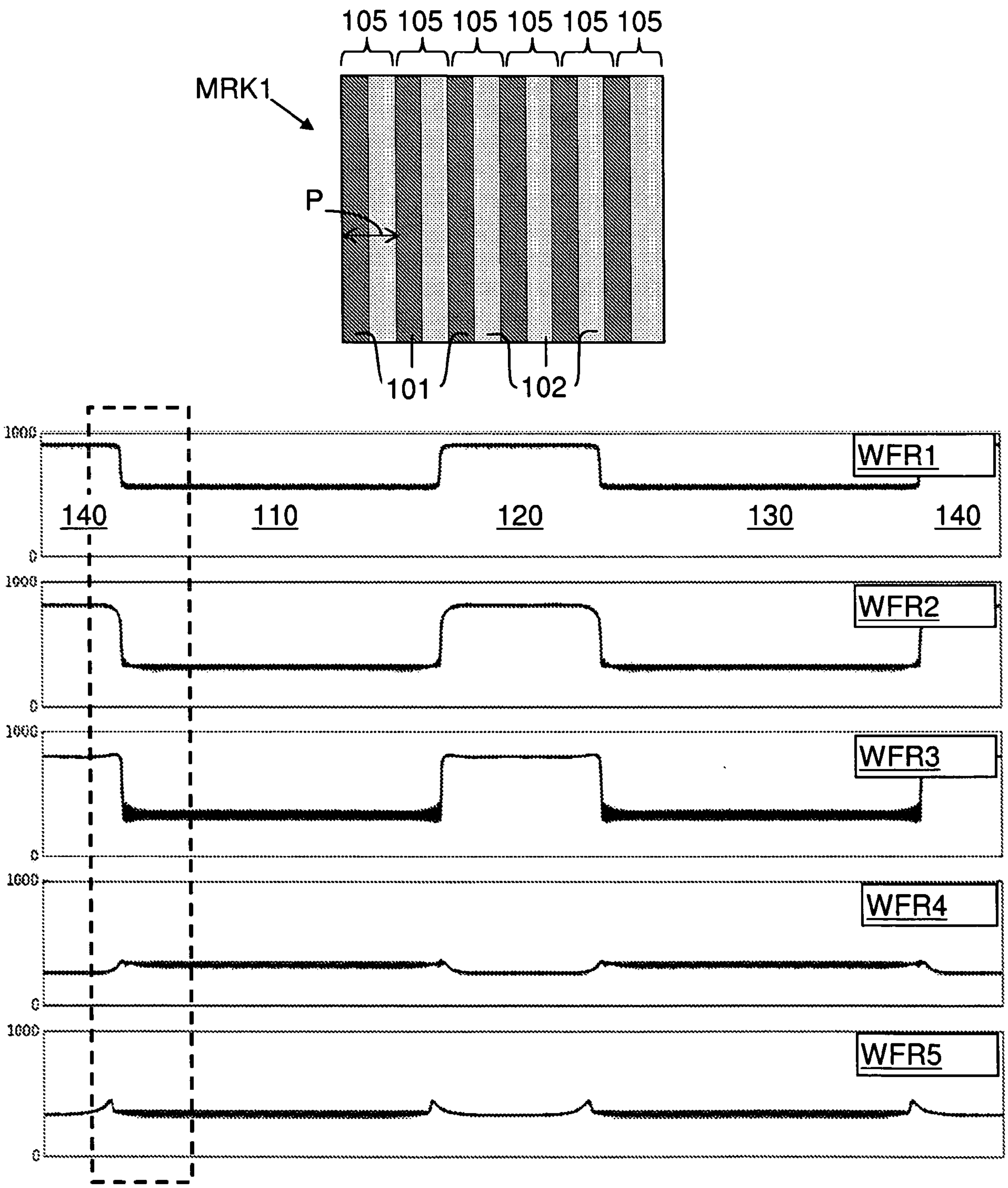
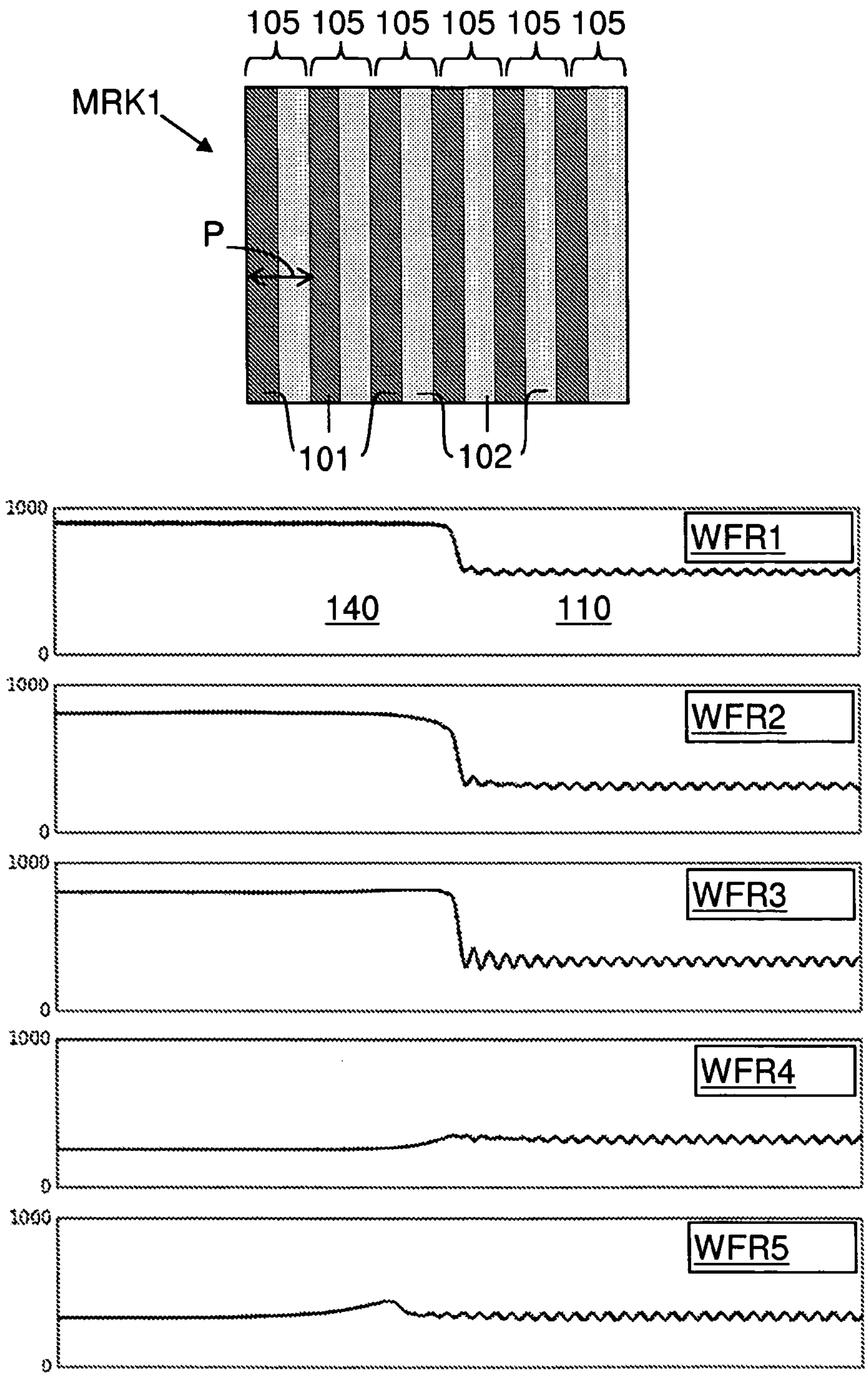
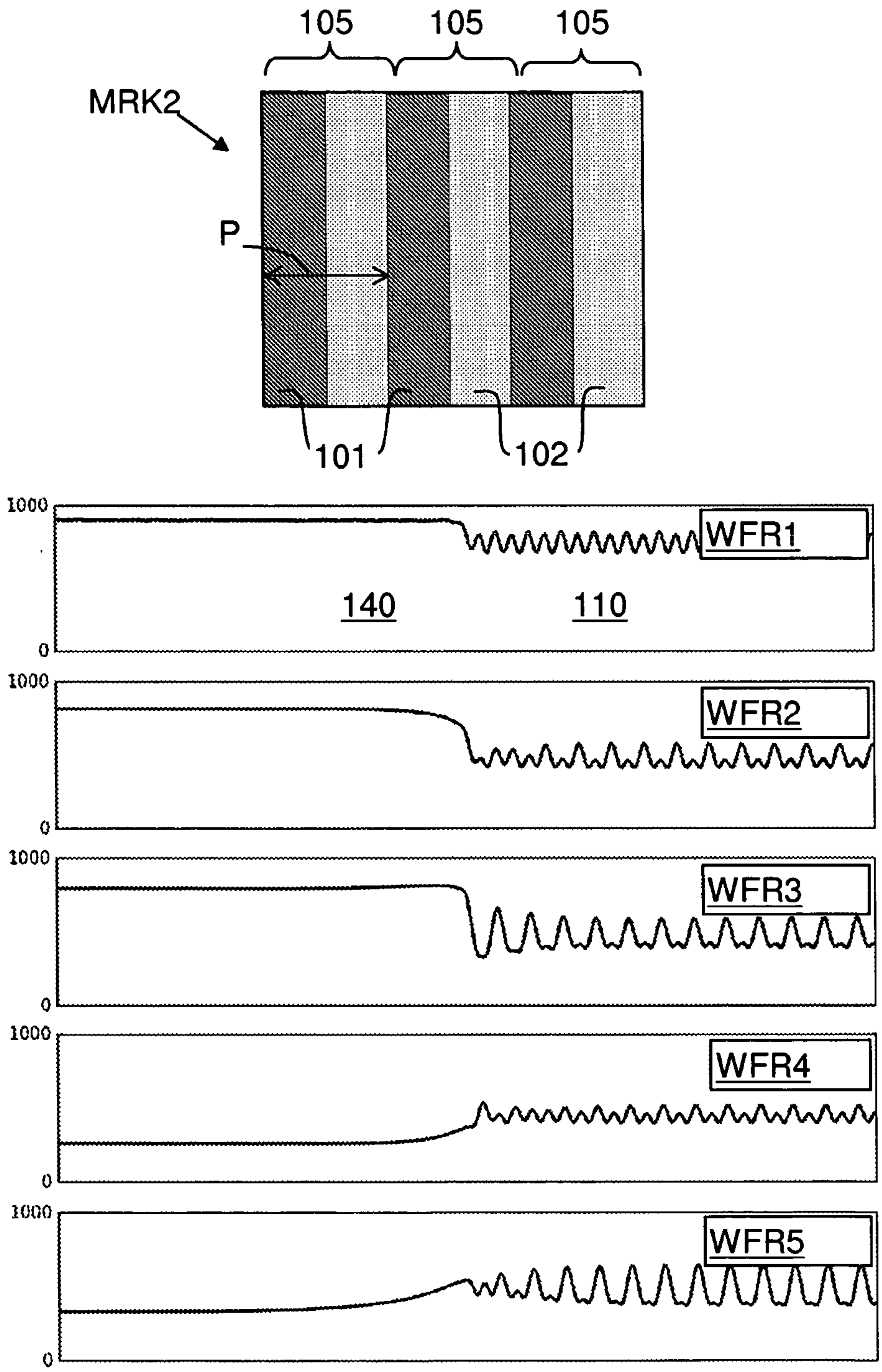

105 105 105 105 105 105
MRK1
P
101
102
1000
0
WFR1
140
110
120
130
140
WFR2
WFR3
WFR4
WFR5

FIG. 10



105 105 105 105 105 105
MRK1
P
101
102
1000
0
WFR1
140
110
WFR2
WFR3
WFR4
WFR5

FIG. 11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102
1000
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1000
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WFR2
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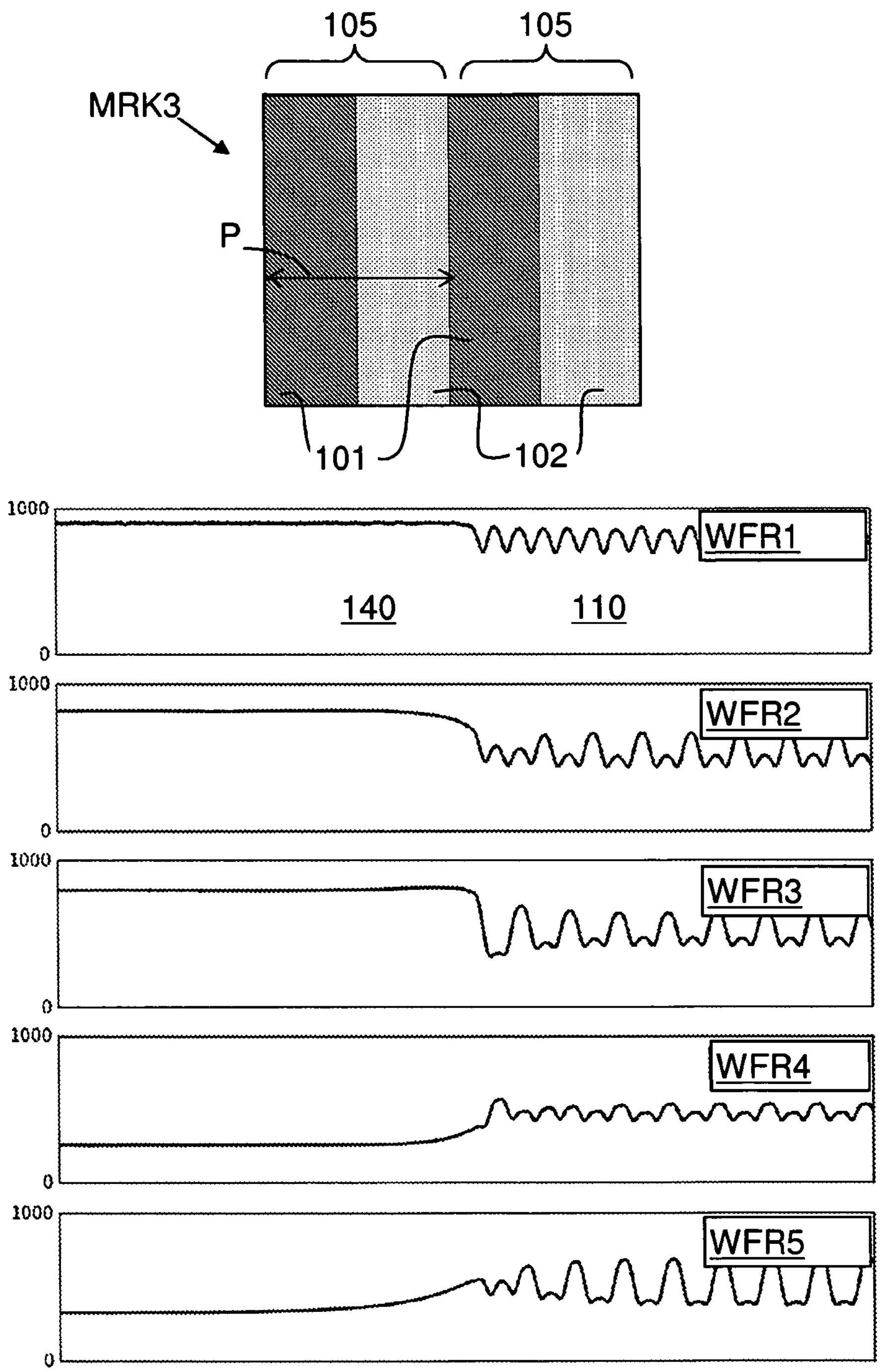
0
WFR3
1000
0
WFR4
1000
0
WFR5

FIG. 12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MRK3
P
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102
1000
WFR1
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1000
WFR3
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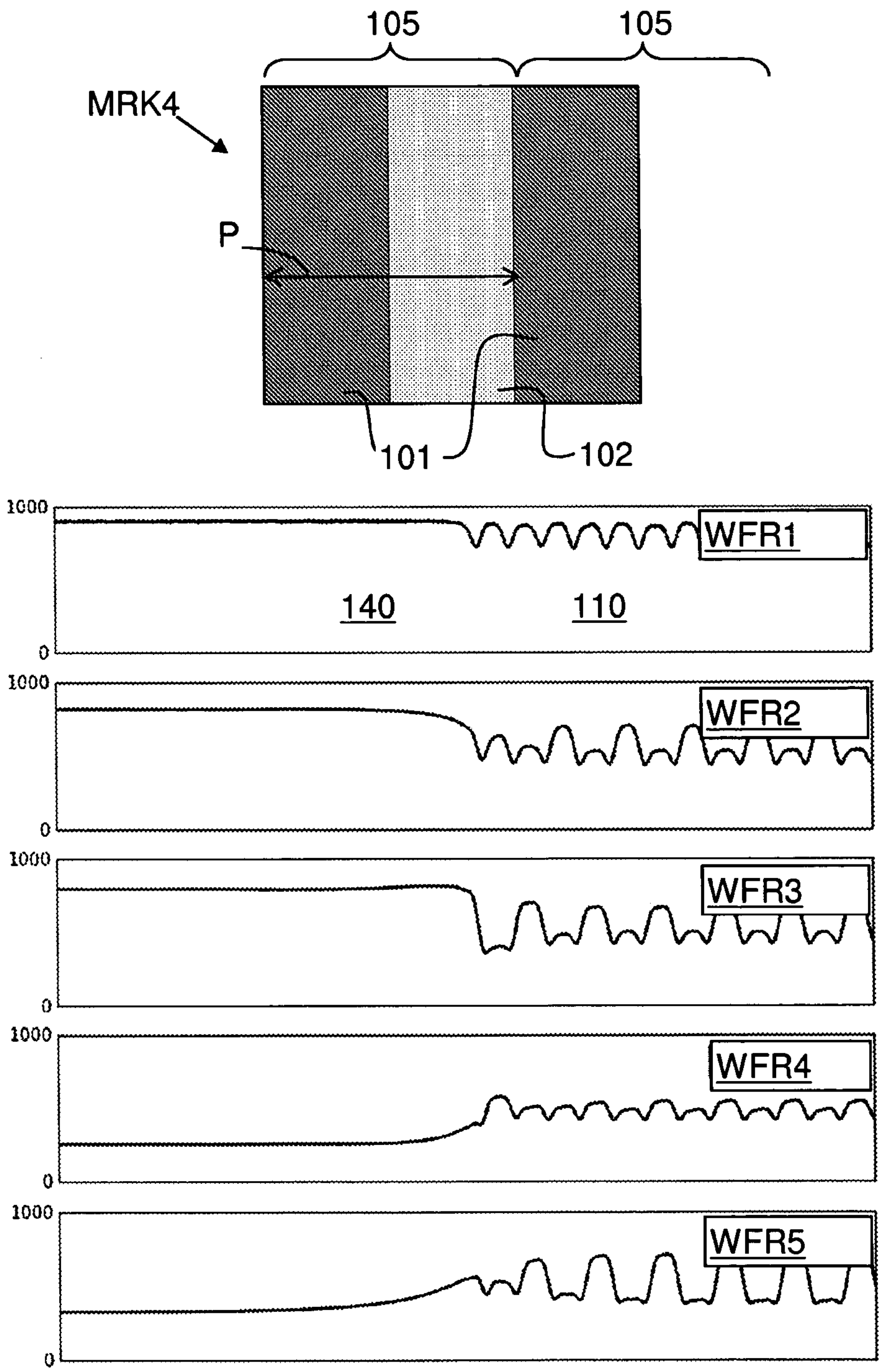
1000
WFR4
0
1000
WFR5
0

FIG. 13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P
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102
1000
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0
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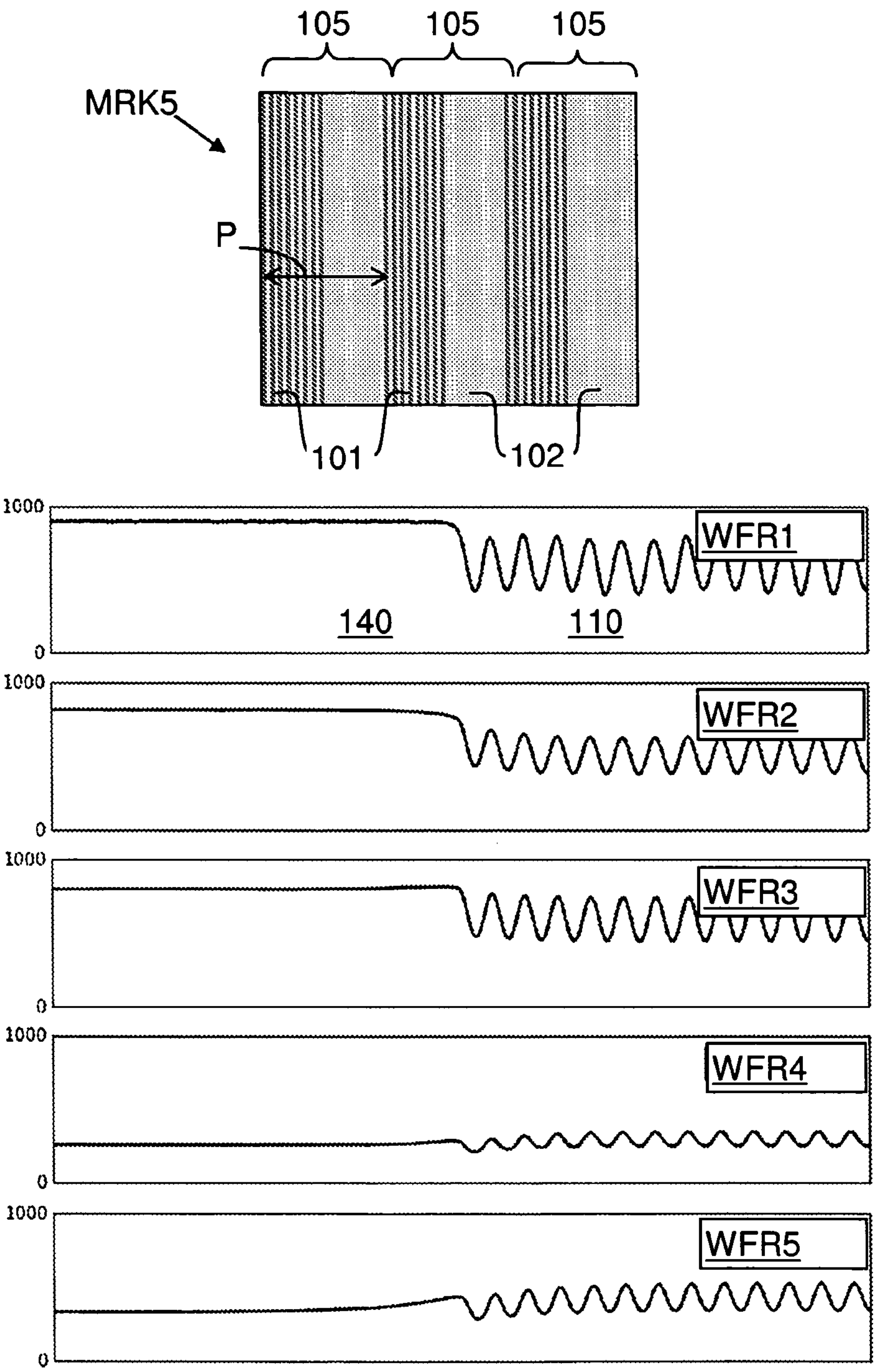
WFR3
1000
0
WFR4
1000
0
WFR5

FIG. 14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MRK5
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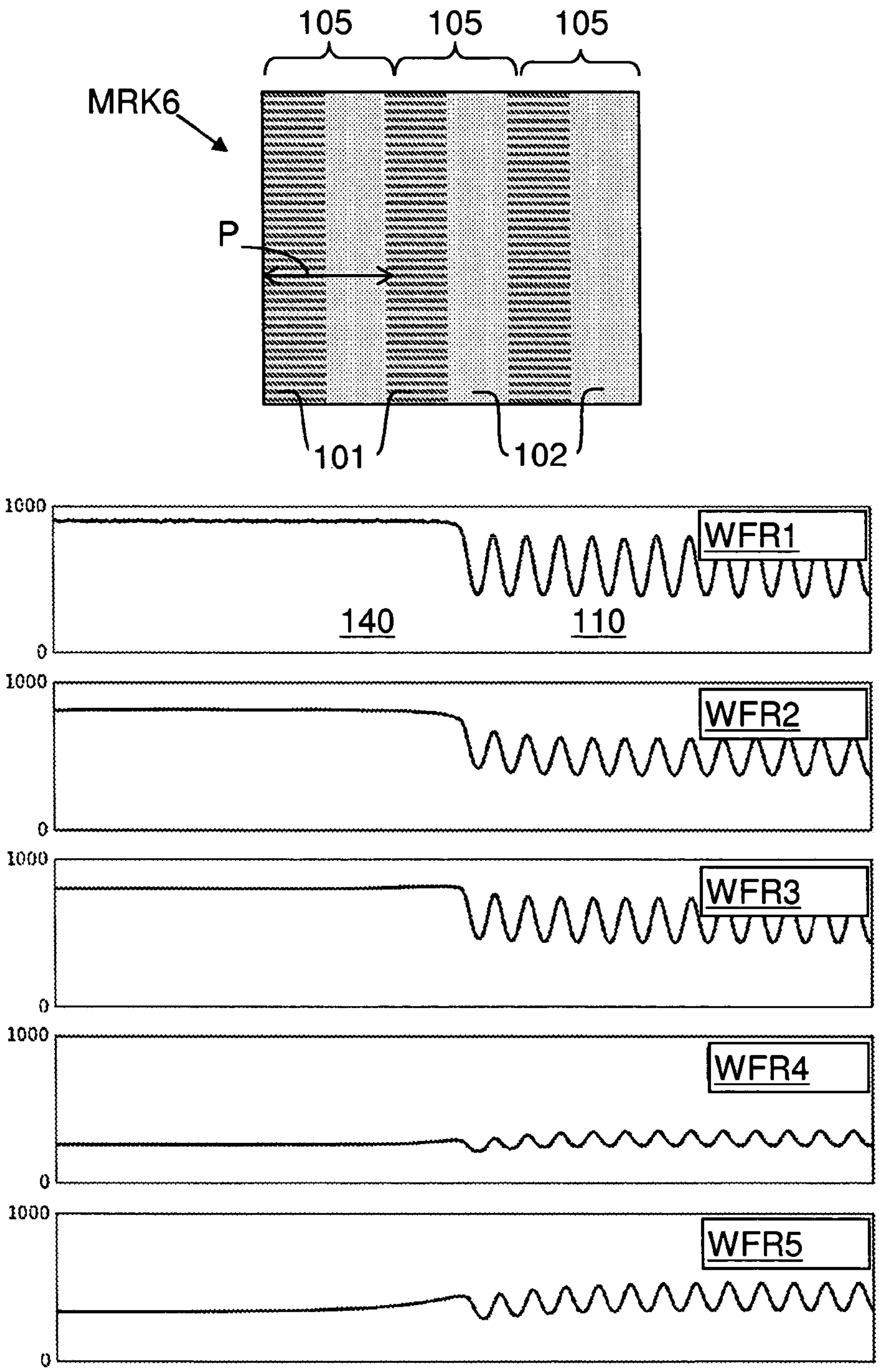
0
WFR4
1000
0
WFR5

FIG. 15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WFR3
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0
WFR4
1000
0
WFR5

FIG. 16

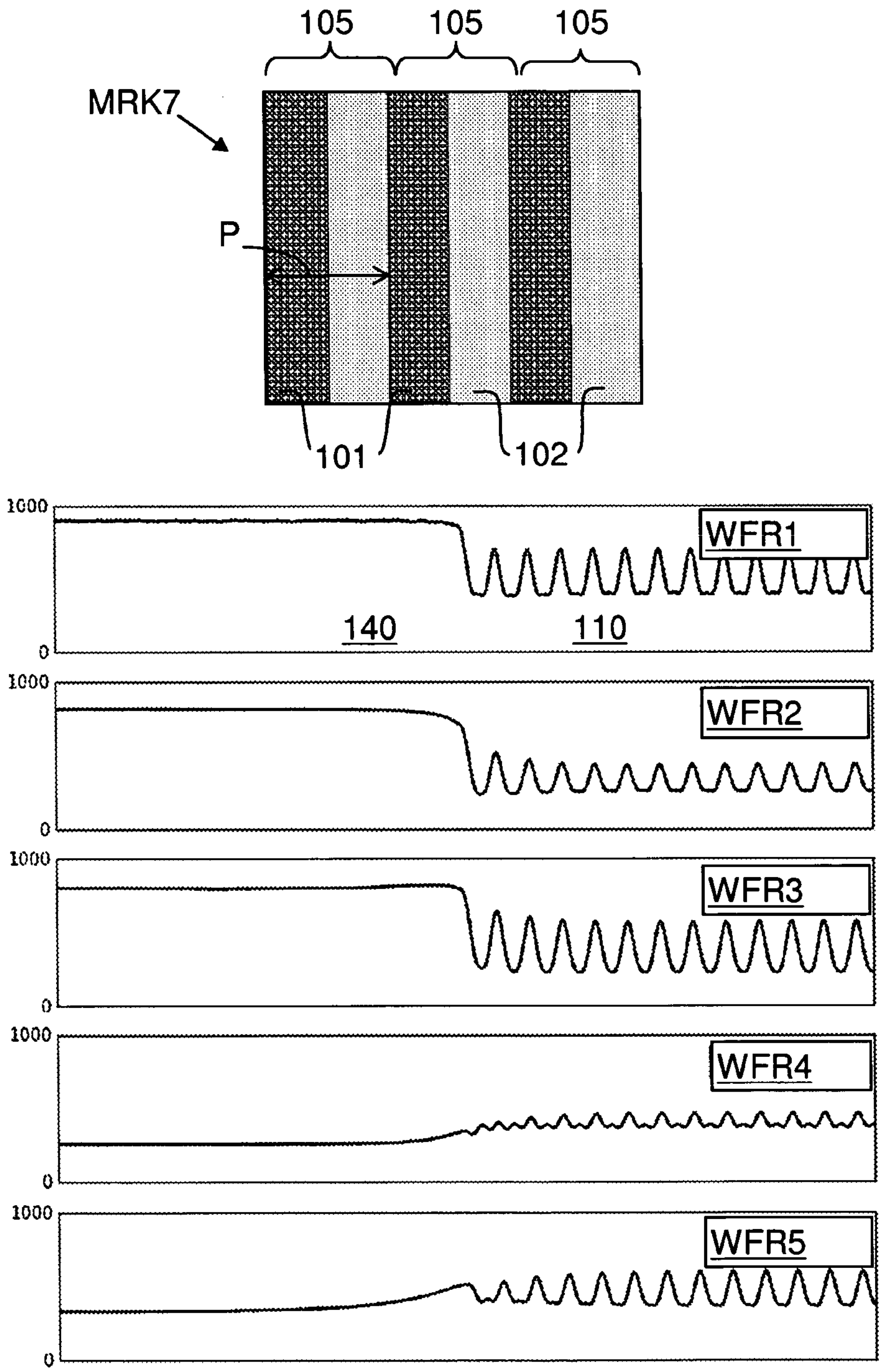
105
105
105
MRK7
P
101
102
1000
0
WFR1
140
110
WFR2
WFR3
WFR4
WFR5

FIG. 17

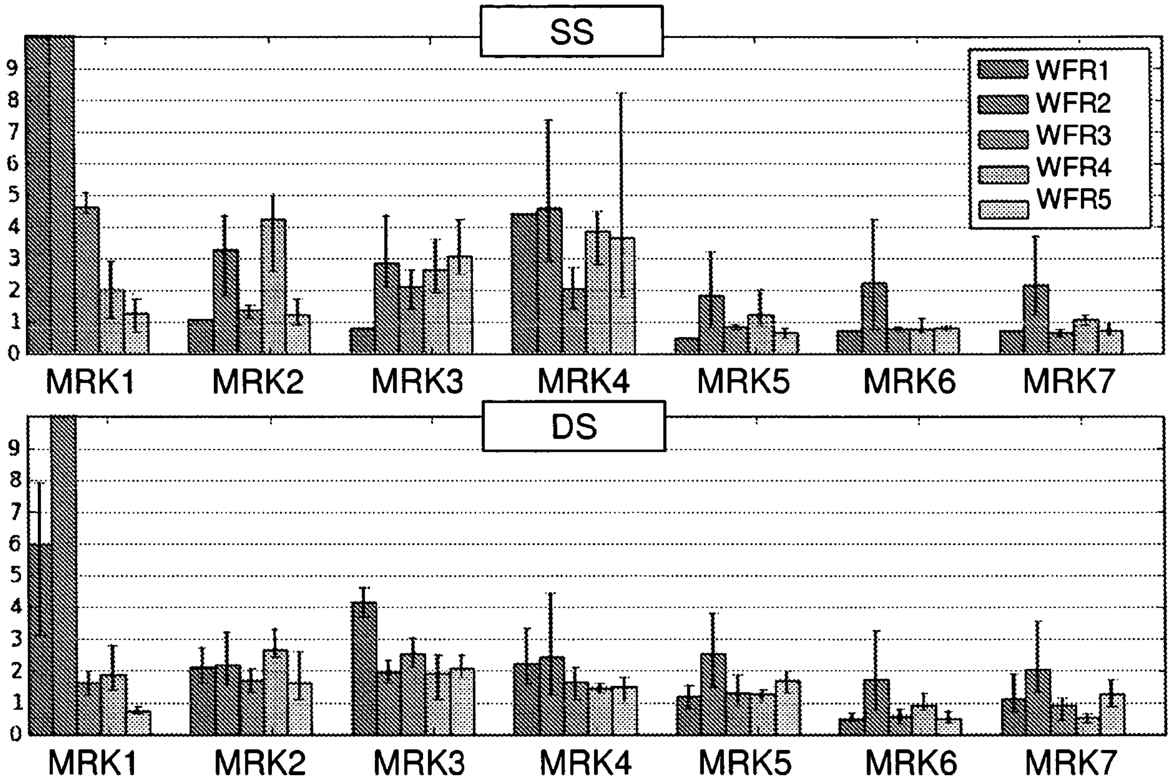
SS
DS
WFR1
WFR2
WFR3
WFR4
WFR5
0
1
2
3
4
5
6
7
8
9
MRK1
MRK2
MRK3
MRK4
MRK5
MRK6
MRK7

FIG. 18

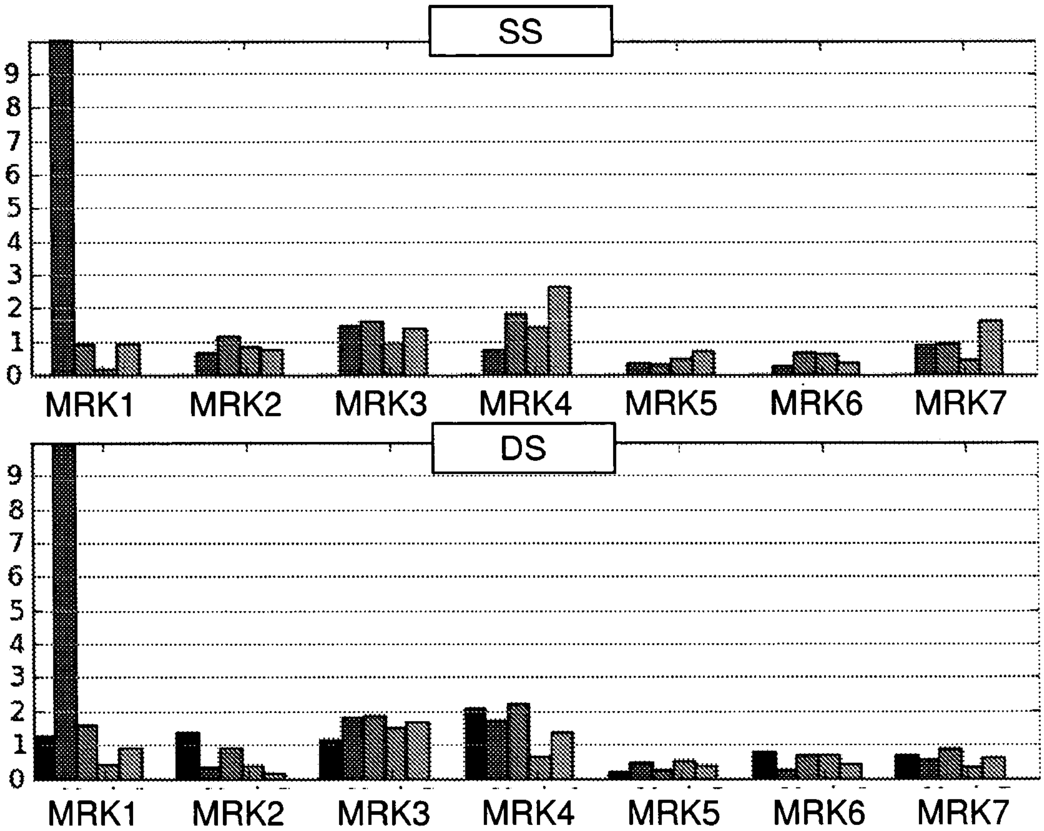
SS
9
8
7
6
5
4
3
2
1
0
MRK1
MRK2
MRK3
MRK4
MRK5
MRK6
MRK7
DS
9
8
7
6
5
4
3
2
1
0
MRK1
MRK2
MRK3
MRK4
MRK5
MRK6
MRK7

FIG. 19

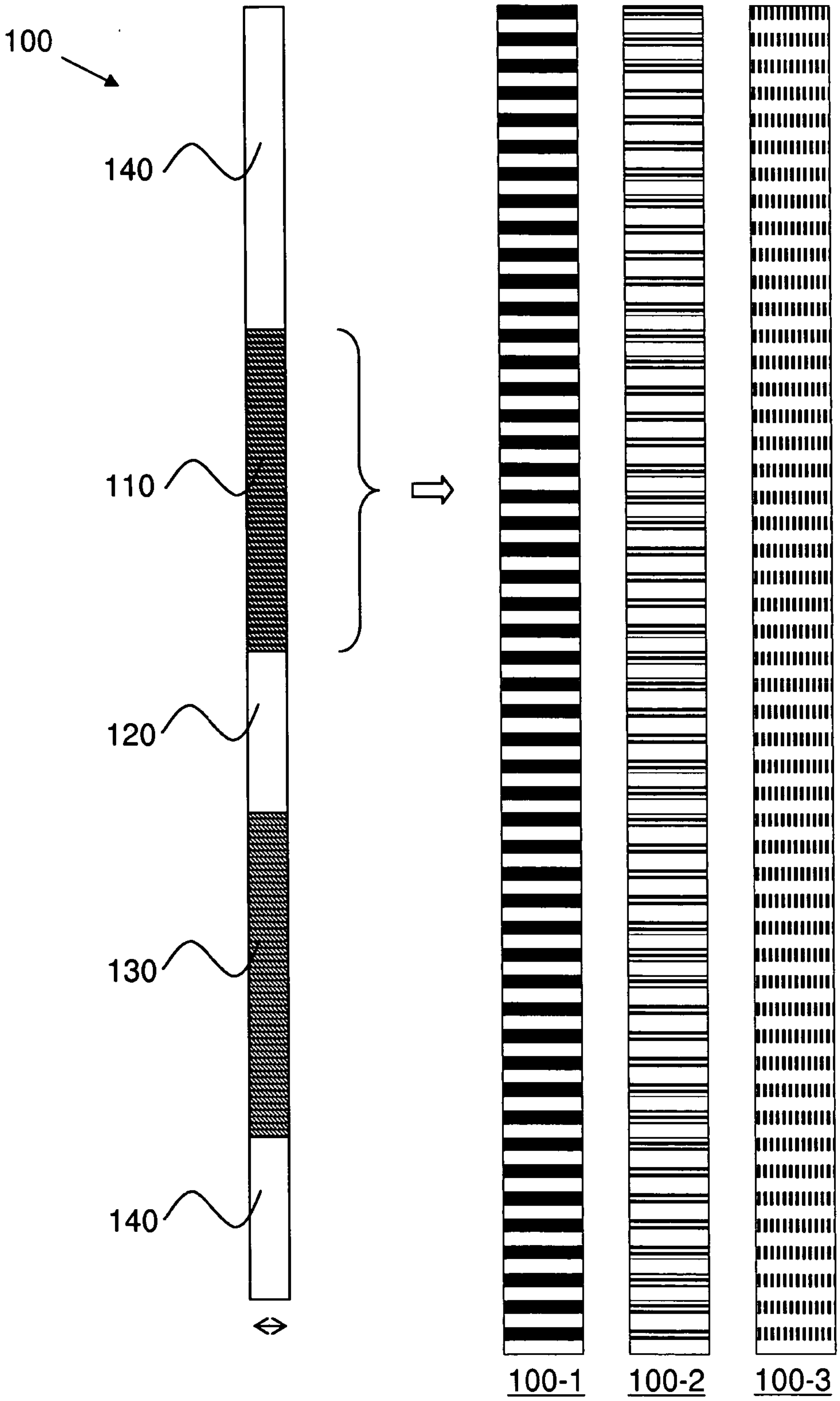

FIG. 20

Agentschap NL
Ministerie van Economische Zaken

OCTROOIAANVRAAG NR.:
NO 138807
NL 2011681

ONDERZOEKSRAPPORT

BETREFFENDE HET RESULTAAT VAN HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK

RELEVANTE LITERATUUR

Categorie[1]	Literatuur met, voor zover nodig, aanduiding van speciaal van belang zijnde tekstgedeelten of figuren.	Van belang voor conclusie(s) nr:	Classificatie (IPC)
X	MEGENS H. ET AL.: "Advances in process overlay - alignment solutions for future technology nodes", PROCEEDINGS OF SPIE, deel 6518, 2007, bladzijden 65181Z1-65181Z12, XP040237953, BELLINGHAM WA 98227-0010 USA DOI: 10.1117/12.712149 * sections 3.2, 3.4, 3.5; figuren 8, 10-14 * -----	1-14	INV. G03F7/20 H01L21/68 H01J37/317
X,D	US 2012/267802 A1 (DE BOER GUIDO [NL] ET AL) 25 oktober 2012 (2012-10-25) * samenvatting; conclusie 1 * * alineas [0056] - [0065] * * figuren 5,6 * & WO 2012/144904 A2 (MAPPER LITHOGRAPHY IP BV [NL]; VERGEER NIELS [NL]; DE BOER GUIDO [NL]) 26 oktober 2012 (2012-10-26) -----	15-28	

Onderzochte gebieden van de techniek: G01B, G03F, H01J, H01L

Indien gewijzigde conclusies zijn ingediend, heeft dit rapport betrekking op de conclusies ingediend op:

Plaats van onderzoek:	Datum waarop het onderzoek werd voltooid:	Bevoegd ambtenaar:
's-Gravenhage	7 februari 2014	Heryet, Chris

[1] CATEGORIE VAN DE VERMELDE LITERATUUR

X: de conclusie wordt als niet nieuw of niet inventief beschouwd ten opzichte van deze literatuur
Y: de conclusie wordt als niet inventief beschouwd ten opzichte van de combinatie van deze literatuur met andere geciteerde literatuur van dezelfde categorie, waarbij de combinatie voor de vakman voor de hand liggend wordt geacht
A: niet tot de categorie X of Y behorende literatuur die de stand van de techniek beschrijft
O: niet-schriftelijke stand van de techniek
P: tussen de voorrangsdatum en de indieningsdatum gepubliceerde literatuur
T: na de indieningsdatum of de voorrangsdatum gepubliceerde literatuur die niet bezwarend is voor de octrooiaanvrage, maar wordt vermeld ter verheldering van de theorie of het principe dat ten grondslag ligt aan de uitvinding
E: eerdere octrooi(aanvrage), gepubliceerd op of na de indieningsdatum, waarin dezelfde uitvinding wordt beschreven
D: in de octrooiaanvrage vermeld
L: om andere redenen vermelde literatuur
&: lid van dezelfde octrooifamilie of overeenkomstige octrooipublicatie

1

AANHANGSEL BEHORENDE BIJ HET RAPPORT BETREFFENDE HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK, UITGEVOERD IN DE OCTROOIAANVRAGE NR.

NO 138807
NL 2011681

Het aanhangsel bevat een opgave van elders gepubliceerde octrooiaanvragen of octrooien (zogenaamde leden van dezelfde octrooifamilie), die overeenkomen met octrooischriften genoemd in het rapport.
De opgave is samengesteld aan de hand van gegevens uit het computerbestand van het Europees Octrooibureau per
De juistheid en volledigheid van deze opgave wordt noch door het Europees Octrooibureau, noch door het Bureau voor de Industriële eigendom gegarandeerd; de gegevens worden verstrekt voor informatiedoeleinden.

07-02-2014

In het rapport genoemd octrooigeschrift	Datum van publicatie	Overeenkomend(e) geschrift(en)	Datum van publicatie
US 2012267802 A1	25-10-2012	EP 2699967 A2	26-02-2014
		NL 2008679 C	26-06-2013
		NL 2010979 A	01-08-2013
		TW 201250399 A	16-12-2012
		US 2012267802 A1	25-10-2012
		WO 2012144904 A2	26-10-2012

OCTROOICENTRUM NEDERLAND

SCHRIFTELIJKE OPINIE

DOSSIER NUMMER	INDIENINGSDATUM	VOORRANGSDATUM	AANVRAAGNUMMER
NO138807	28.10.2013	26.10.2012	NL2011681
CLASSIFICATIE INV. G03F7/20 H01L21/68 H01J37/317			
AANVRAGER Mapper Lithography IP B.V.			

Deze schriftelijke opinie bevat een toelichting op de volgende onderdelen:

- ☒ Onderdeel I Basis van de schriftelijke opinie
- ☐ Onderdeel II Voorrang
- ☐ Onderdeel III Vaststelling nieuwheid, inventiviteit en industriële toepasbaarheid niet mogelijk
- ☐ Onderdeel IV De aanvraag heeft betrekking op meer dan één uitvinding
- ☒ Onderdeel V Gemotiveerde verklaring ten aanzien van nieuwheid, inventiviteit en industriële toepasbaarheid
- ☐ Onderdeel VI Andere geciteerde documenten
- ☐ Onderdeel VII Overige gebreken
- ☐ Onderdeel VIII Overige opmerkingen

	DE BEVOEGDE AMBTENAAR
	Heryet, Chris

Aanvraag nr.:

SCHRIFTELIJKE OPINIE

NL2011681

Onderdeel I Basis van de Schriftelijke Opinie

1. Deze schriftelijke opinie is opgesteld op basis van de meest recente conclusies ingediend voor aanvang van het onderzoek.

2. Met betrekking tot **nucleotide en/of aminozuur sequenties** die genoemd worden in de aanvraag en relevant zijn voor de uitvinding zoals beschreven in de conclusies, is dit onderzoek gedaan op basis van:

   a. type materiaal:

   ☐ sequentie opsomming

   ☐ tabel met betrekking tot de sequentie lijst

   b. vorm van het materiaal:

   ☐ op papier

   ☐ in elektronische vorm

   c. moment van indiening/aanlevering:

   ☐ opgenomen in de aanvraag zoals ingediend

   ☐ samen met de aanvraag elektronisch ingediend

   ☐ later aangeleverd voor het onderzoek

3. ☐ In geval er meer dan één versie of kopie van een sequentie opsomming of tabel met betrekking op een sequentie is ingediend of aangeleverd, zijn de benodigde verklaringen ingediend dat de informatie in de latere of additionele kopieën identiek is aan de aanvraag zoals ingediend of niet meer informatie bevatten dan de aanvraag zoals oorspronkelijk werd ingediend.

4. Overige opmerkingen:

Aanvraag nr.:

SCHRIFTELIJKE OPINIE

NL2011681

Onderdeel V Gemotiveerde verklaring ten aanzien van nieuwheid, inventiviteit en industriële toepasbaarheid

1. Verklaring

Nieuwheid	Ja:	Conclusies	15-28
	Nee:	Conclusies	1-14
Inventiviteit	Ja:	Conclusies	
	Nee:	Conclusies	1-28
Industriële toepasbaarheid	Ja:	Conclusies	1-28
	Nee:	Conclusies	

2. Citaties en toelichting:

Zie aparte bladzijde

Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1 **Documents cited in this opinion**

1.1 Reference is made to the following documents.

D1 MEGENS H. ET AL.: "Advances in process overlay - alignment solutions for future technology nodes", PROCEEDINGS OF SPIE, vol. 6518, 2007, pages 65181Z1-65181Z12, BELLINGHAM WA 98227-0010 USA; XP040237953; DOI: 10.1117/12.712149

D2 US 2012/267802 A1 (DE BOER GUIDO [NL] ET AL) 25 October 2012

1.2 Document D2 corresponds to the international application cited on page 8 of the present application and published on the earlier of the two priority dates of the present application. Document D2 was published on the previous day and so belongs to the prior art irrespective of the validity of the priorities claimed by the present application.

2 **Apparatus defined by claim 1**

2.1 Claim 1 reads as follows (text formatting and labelling introduced by the international searching authority):

S) *Substraat (12,513) omvattend*

M0) *een optische positiemarkering (100)*

M0.1) *om te worden uitgelezen door een optische opnamekop (500) voor het uitzenden van licht van een vooraf bepaalde golflengte, bij voorkeur rood of infrarood licht, meer in het bijzonder van 635 nm licht,*

waarbij de optische positiemarkering (100)

M1) *een markeringshoogte (MH),*

M2) *een markeringslengte (ML) en*

M3) *een vooraf bepaalde bekende positie op het substraat (12,513)*

heeft,

waarbij de optische positiemarkering (100)

M4) *zich uitstrekt langs een lengterichting (x) en*

M5) *is gerangschikt voor het langs de lengterichting (x) variëren van een* *reflectiecoëfficiënt van de positiemarkering (100),*

waarbij de optische positiemarkering (100) omvat:

R1) *- een eerste gebied (101) met*

R1.1) *een eerste reflectiecoëfficiënt en*

R1.2) *een eerste breedte (W);*

R2) *- een tweede gebied (102)*

R2.1) *naburig aan het eerste gebied (101) en*

R2.2) *een eerste gebiedspaar (105) vormend,*

waarbij het tweede gebied 102)

R2.3a) *een tweede reflectiecoëfficiënt heeft en*

R2.4) *een tweede breedte (W),*

R2.3b) *en de tweede reflectiecoëfficiënt verschillend is van de eerste reflectiecoëfficiënt,*

R1.3) *waarbij het eerste gebied (101) subgolflengte-structuren (SWS) omvat in vergelijking met een golflengte van het licht van vooraf bepaalde golflengte.*

<u>Claim interpretation</u>

2.2 Claim text S, M0, M0.1, M1, M2, M3, M4, M5 defines a substrate comprising an mark having an optical reflection coefficient which varies in a direction of elongation of the mark.

2.3 Claim text R1, R1.1, R1.2, R2, R2.1, R2.2, R2.3a, R2.4, R2.3b specifies that the mark comprises a pair of elongated neighbouring regions having different reflection coefficients.

2.4 In combination with claim text M0.1, claim text R1.3 specifies that one of the regions (the first) comprises structures which are smaller than a wavelength of light which could be used to detect the mark.

<u>Lack of novelty</u>

2.5 **Document D1** discloses three types of alignment mark developed by ASML:

- A standard Versatile Scribelane Primary Mark (VSPM); see section 3.2 and figure 8(a).
- An optimised VSPM; see section 3.2 and figure 8(b).
- A segmented VSPM optimised taking account of polarisation and called a POLAR mark; see sections 3.4, 3.5, especially figure 11.

2.6 The **POLAR mark** shown in **figure 11** comprises a pair of outer gratings for coarse alignment and pair of inner gratings for fine alignment. The mark is detected by light having a wavelength of at least 532nm in order to avoid exposing the resist on the wafer; see section 3.5, first paragraph. Therefore, document D1 discloses a substrate according to claim text S, M0, M0.1, M1, M2, M3, M4.

2.7 The AA5 portion of the left-hand fine alignment grating comprises a regular pattern of pairs of neighbouring regions (1.6µm wide lines and 1.6µm wide spaces) having different reflection coefficients according to claim text M5, R1, R1.1, R1.2, R2, R2.1, R2.2, R2.3a, R2.4, R2.3b.

2.8 The 1.6µm wide lines comprise "sub-segmentation" lines of 200nm width according to claim text M1.3. *(The 1.6µm wide spaces in the AA5 segment comprise "sub-segmentation" lines of similar width).*

2.9 It is therefore considered that the substrate defined by claim 1 is not novel.

3 **Substrates defined by dependent claims 2-14**

3.1 The above-mentioned parts of document D1 also disclose the additional features of claims 2-14 (compare D1 figure 11 and figure 9 of the present application).

3.2 It is therefore considered that the substrates defined by these claims are also not novel.

4 **Alignment method defined by claim 21**

4.1 Claim 21 reads as follows (text formatting and labelling introduced by the international searching authority):

A0) *Werkwijze voor het bepalen van een positie van een substraat (12,513) in een lithografiesysteem (1),*

A0.1) *waarbij het systeem (1) een optische uitlijnsensor (SS,DS) omvat voor het uitzenden van een lichtstraal (511) naar het substraat (12,513) en voor het meten van een intensiteitprofiel (fig. 7) van een nulde orde gereflecteerde lichtstraal,*

waarbij de werkwijze omvat:

A1) *- het verschaffen van een substraat (12,513) omvattend een optische positiemarkering (100) met een markeringsbreedte (MW), een markeringslengte (ML) en een vooraf bekende positie op het substraat (12,513), waarbij de optische positiemarkering (100) zich uitstrekt langs een lengterichting (x) en is ingericht voor het variëren van een reflectiecoëfficiënt* *van de positiemarkering (100) langs de lengterichting (x);*

A2) *- het bewegen van het substraat (12,513) zodanig dat de optische positiemarkering (100) in hoofdzaak nabij de optische uitlijnsensor (SS,DS) is in overeenstemming met een geschatte positie van de optische positiemarkering (100) ten opzichte van de optische uitlijnsensor (SS,DS);*

A3) *- het scannen van de optische positiemarkering (100) langs een scanpad in de lengterichting met de optische uitlijnsensor (100) om een gemeten intensiteitprofiel te verkrijgen met een scanlengte,*

A3.1) *waarbij de scanlengte langer is dan de markeringslengte (ML);*

A4) *- het vergelijken van het gemeten intensiteitprofiel (fig. 7) met een verwacht intensiteitprofiel (fig. 6) geassocieerd met de optische positiemarkering (100) om een verschil (x) te bepalen tussen een werkelijke positie van de optische positiemarkering (100) en de geschatte positie, en*

A5) *- het bepalen van de werkelijke positie van de positiemarkering uit het scanpad en het verschil.*

4.2 **Document D2** (abstract; claim 1; paragraphs 56-65; figures 5, 6) discloses a method of scanning and optically detecting an alignment mark comprising subresolution structures arranged to cause a variation in a specular reflection coefficient along the the length of the mark according to claim text **A, A0.1, A1, A2, A3**.

4.3 Document D2 does not disclose a scan which is longer than the mark according to claim text A3.1 and does not disclose determination of position on the basis of a comparison between the detected signal and a reference signal according to claim text A4, A5.

4.4 It is therefore considered that the method defined by claim 21 is novel.

4.5 The above-mentioned method is considered as the closest prior art for the method defined by claim 21.

4.6 The claimed method **differs** from the known method in the provision of a scan according to claim text **A3.1** and steps according to claim text **A4, A5**.

4.7 The **technical effect** of this difference is to acquire a waveform which may correspond to the entire mark, and to determine the position of the measured waveform with respect to an expected (i.e. reference) waveform.

4.8 This solves the **problem** of accurately determining the position of the mark.

4.9 It is generally known that an accurate determination of the position of a measured waveform requires a comparison between the whole waveform (possibly ignoring any distorted or noisy portions) and a reference waveform (rather than simply comparing the position of a single point on the waveform with a reference point). The offset between the two waveforms which gives the best match is then generally regarded as a good indication of the position of the measured waveform with respect to the reference waveform.

4.10 The person skilled in alignment for lithographic processing would then as a matter of routine acquire a waveform from the full mark according to claim text A3.1 and compare this with a reference according claim text **A4, A5.**

4.11 It is therefore considered that the method defined by claim 21 does not involve an inventive step.

5 **Alignment methods defined by dependent claims 22-27**

5.1 The additional features of claims 22-27 appear to a matter of routine in the field of lithography alignment and do not appear to solve a problem which can be understood from the description.

5.2 It is therefore considered that the methods defined by these claims also do not involve an inventive step.

6 **Lithography systems defined by claims 15-20, 28** *(for processing a substrate according to one of claims 1-14 and configured to carry out an alignment method according to one of claims 21-27)*

6.1 Since the lithography systems disclosed in the above-mentioned parts of document D2 would be suitable for processing a substrate according to any one of claims 1-14, the opinions on claims 21-27 apply *mutatis mutandis* to the lithography systems defined by claims 15-20, 28.

6.2 It is therefore considered that the lithography systems defined by claims 15-20, 28 do not involve an inventive step.

7 **Conclusion**

7.1 As explained above, it is considered that the subject matter of the claims is not novel and inventive.

7.2 Since the application relates to semiconductor lithography, the subject matter of the claims is industrially applicable.

7.3 Therefore, the application does not satisfy all the criteria for patentability.