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(54) **A device for transmission image detection for use in a lithographic projection apparatus and a method for determining third order distortions of a patterning device and/or a projection system of such a lithographic apparatus.**

(57) The invention relates to a device for transmission image detection for use in a lithographic projection apparatus. The device comprises an array of gratings and an array of radiation sensitive sensors each of which is arranged to receive radiation coming through one of said gratings. The array of radiation sensitive sensors may be a 1-dimensional diode array.

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A device for transmission image detection for use in a lithographic projection apparatus and a method for determining third order distortions of a patterning device and/or a projection system of such a lithographic apparatus

Field

The present invention relates to a device for transmission image detection for use in a lithographic projection apparatus.

Background

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

In present lithographic projection apparatus, a device for transmission image detection is used in order to align a reticle to a wafer stage. It consists of a structure (e.g. grating) on a reticle and a complementary structure on a Transmission image detector plate. The aerial image of the structure is scanned using the Transmission image detector to determine position and focus of the image. The Transmission image detector has a small number (4-8) of such structures. Beneath each structure a photodiode is located to detect the light. With the current Transmission image detector, only two X-positions and two Y-positions can be measured simultaneously in the image field (one left in the image field and one right in the image field). With only four measurement positions in the image field the Transmission image detector can only measure position, magnification and rotation of the reticle with respect to the wafer stage. Higher order distortions, such as D3 (third order distortion) remain undetected. Such distortions arise as a consequence of reticle heating and/or lens heating.

SUMMARY

It is desirable to detect third order distortions and field curvature of a lithographic projection apparatus using a Transmission image detector.

According to an aspect of the invention, there is provided a device for transmission image detection comprising an array of gratings and an array of radiation sensitive sensors each of which is arranged to receive radiation coming through one of said gratings.

In a further aspect, the invention relates to a lithographic apparatus comprising:
- an illumination system configured to condition a radiation beam;
- a patterning device being capable of imparting the radiation beam with a pattern in its cross-section to form a patterned radiation beam, the patterning device comprising an array of first gratings;
- a substrate table constructed to hold a substrate; and
- a projection system configured to project the patterned radiation beam onto a target portion of the substrate,
- a device for transmission image detection arranged on the substrate table, the device for transmission image detection comprising an array of second gratings and an array of radiation sensitive sensors each of which is arranged to receive radiation coming through one of the first gratings and through one of the second gratings;

- a processing device arranged to calculate third order distortions of at least one of the patterning device and the projection system using signals received from the radiation sensitive sensors.

The invention also relates to a method for determining third order distortions of at least one of a patterning device and a projection system of a lithographic apparatus, the method comprising:

- creating a radiation beam;
- imparting the radiation beam with a pattern in its cross-section to form a patterned radiation beam using a patterning device, the patterning device comprising an array of gratings;
- providing a device for transmission detection on the substrate, the device for transmission detection comprising an array of gratings and an array of radiation sensitive sensors arranged to receive radiation coming through the gratings and to produce measurement signals;
- sensing radiation coming through the gratings of the patterning device and through the gratings of the device for transmission detection;
- determining third order distortions of at least one of the patterning device and the projection system, using the measurement signals.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying schematic drawings in which corresponding reference symbols indicate corresponding parts, and in which:

- Figure 1 depicts a lithographic apparatus according to the state of the art;
- Figure 2 depicts schematically a Transmission image detector according to the state of the art;
- Figure 3 shows an example of a Transmission image detector according to the state of the art;
- Figure 4 shows a Transmission image detector according to an embodiment of the

invention;

- Figure 5 is an example of a reticle that may be used with the Transmission image detector of Figure 4;
- Figure 6 shows an example of an array of gratings in which X-gratings alternate with Y-gratings.

DETAILED DESCRIPTION

Figure 1 schematically depicts a lithographic apparatus according to the state of the art. The apparatus comprises:

- an illumination system (illuminator) IL configured to condition a radiation beam B (e.g. UV radiation or DUV radiation).
- a support structure (e.g. a mask table) MT constructed to support a patterning device (e.g. a mask) MA and connected to a first positioner PM configured to accurately position the patterning device in accordance with certain parameters;
- a substrate table (e.g. a wafer table) WT constructed to hold a substrate (e.g. a resist-coated wafer) W and connected to a second positioner PW configured to accurately position the substrate in accordance with certain parameters; and
- a projection system (e.g. a refractive projection lens system) PS configured to project a pattern imparted to the radiation beam B by patterning device MA onto a target portion C (e.g. comprising one or more dies) of the substrate W.

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

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

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

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

The term "projection system" used herein should be broadly interpreted as encompassing any type of projection system, including refractive, reflective, catadioptric, magnetic, electromagnetic and electrostatic optical systems, or any combination thereof, as appropriate for the exposure radiation being used, or for other factors such as the use of an immersion liquid or the use of a vacuum. Any use of the term "projection lens" herein may be considered as synonymous with the more general term "projection system".

As here depicted, the apparatus is of a transmissive type (e.g. employing a transmissive mask). Alternatively, the apparatus may be of a reflective type (e.g. employing a programmable mirror array of a type as referred to above, or employing a reflective mask).

The lithographic apparatus may be of a type having two (dual stage) or more substrate tables (and/or two or more mask tables). In such "multiple stage" machines the additional tables may be used in parallel, or preparatory steps may be carried out on one or more tables while one or more other tables are being used for exposure.

The lithographic apparatus may also be of a type wherein at least a portion of the substrate may be covered by a liquid having a relatively high refractive index, e.g. water, so as to fill a space between the projection system and the substrate. An immersion liquid may also be applied to other spaces in the lithographic apparatus, for example, between the mask and the projection system. Immersion techniques are well known in the art for increasing the numerical aperture of projection systems. The term "immersion" as used herein does not mean that a structure, such as a substrate, must be submerged in liquid, but rather only means that liquid is located between the projection system and the substrate during exposure.

Referring to Figure 1, the illuminator IL receives a radiation beam from a radiation source SO. The source and the lithographic apparatus may be separate entities, for example when the source is an excimer laser. In such cases, the source is not considered to form part of the lithographic apparatus and the radiation beam is passed from the source SO to the illuminator IL with the aid of a beam delivery system BD comprising, for example, suitable directing mirrors and/or a beam expander. In other cases the source may be an integral part of the lithographic apparatus, for example when the source is a mercury lamp. The source SO and the illuminator IL, together with the beam delivery system BD if required, may be referred to as a radiation system.

The illuminator IL may comprise an adjuster AD for adjusting the angular intensity distribution of the radiation beam. Generally, at least the outer and/or inner radial extent (commonly referred to as σ-outer and σ-inner, respectively) of the intensity distribution in a pupil plane of the illuminator can be adjusted. In addition, the illuminator IL may comprise various other components, such as an integrator IN and a condenser CO. The illuminator may be used to condition the radiation beam, to have a desired uniformity and intensity distribution in its cross-section.

The radiation beam B is incident on the patterning device (e.g., mask MA), which is held on the support structure (e.g., mask table MT), and is patterned by the patterning device. Having traversed the mask MA, the radiation beam B passes through the projection system PS, which focuses the beam onto a target portion C of the substrate W. With the aid of the second positioner PW and position sensor IF (e.g. an interferometric device, linear encoder or capacitive sensor), the substrate table WT can be moved accurately, e.g. so as to position different target portions C in the path of the radiation beam B. Similarly, the first positioner PM and another position sensor (which is not explicitly depicted in Figure 1) can be used to accurately position the mask MA with respect to the path of the radiation beam B, e.g. after mechanical retrieval from a mask library, or during a scan. In general, movement of the mask table MT may be realized with the aid of a long-stroke module (coarse positioning) and a short-stroke module (fine positioning), which form part of the first positioner PM. Similarly, movement of the substrate table WT may be realized using a long-stroke module and a short-stroke module, which form part of the second positioner PW. In the case of a stepper (as opposed to a scanner) the mask table MT may be connected to a short-stroke actuator only, or may be fixed. Mask MA and substrate W may be aligned using mask alignment marks M1, M2 and substrate alignment marks P1, P2. Although the substrate alignment marks as illustrated occupy dedicated target portions, they may be located in spaces between target portions (these are known as scribe-lane alignment marks). Similarly, in situations in which more than one die is provided on the mask MA, the mask alignment marks may be located between the dies.

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

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

imaged in a single static exposure.

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

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

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

Figure 2 depicts schematically a device for transmission image detection, also referred to as a Transmission image detector. A Transmission image detector per se is known from the prior art. The projection Beam PB is incident on a first object G0 for example a grating in the mask MA. The first grating G0 comprises a plurality of openings arranged for creating an image from the projection beam PB. The openings in the first grating G0 each emit a radiation beam RB originating from the projection beam PB. The radiation beams emitted by the plurality of openings in G0, pass through a lens for example, the projection lens system PL. The optical properties of such projection lens system are such that an aerial image 1000 of the first grating G0 is formed at a given plane below the projection lens system PL. The Transmission image detector is positioned below the projection lens system PL. The Transmission image detector comprises a slot pattern G1 and a photo sensor device PS. The slot pattern G1 is an opening over the photo sensor device PS which has the shape of a slit or a square. Advantageously, applying a pattern on the opening over the photo sensor device PS increases the number of edges which may increase the signal level and thus the signal/noise ratio of the photo sensor PS.

The Transmission image detector is arranged on the substrate table WT, see Figure 1, for transfer relative to the position of the projection lens system PL and the mask MA in three orthogonal directions X, Y, and Z. By scanning along these three directions the intensity of the aerial image can be mapped as a function of the XYZ position of the Transmission image detector, for example in an image map (a 3D map), which comprises the coordinates of sampling locations and the intensity sampled at each location. From the 3D map, computational means connected to the Transmission image detector can derive the position of the aerial image by for example a parabolic fit of the top position using a least squares fitting method.

Figure 3 shows an example of a Transmission image detector 29 according to the state of the art with 4 gratings 30, 31, 32, 33 in a litho layer 34. The litho layer 34 is manufactured on a quartz window 35. Beneath each of the gratings 30, 31, 32, 33 an associated photodiode 36, 37, 38, 39 is provided. With only 4 measurement positions in the image field the Transmission image detector 29 can only measure position, magnification, rotation, focus and focus tilt of the reticle with respect to the wafer stage. Higher order distortions, such as D3 (third order distortion) remain undetected. Such distortions arise as a consequence of reticle heating and/or lens heating.

Figure 4 shows a Transmission image detector according to an embodiment of the invention. In this embodiment, the Transmission image detector 40 comprises an array of gratings 41 arranged on a litho layer 42. In Figure 4 each grating is positioned so as to receive an aerial image 44 produced by an associated grating on a reticle (i.e. patterning device) placed on the mask table MT of the lithographic apparatus, see Figure 1. The Transmission image detector 40 further comprises an array of radiation sensitive sensors

46 arranged to receive radiation coming through one of the gratings and to produce a measurement signal. The litho layer may for example be Chrome layer patterned with a plurality of gratings arranged in a row. The litho layer 42 contains the gratings 41 (x and y gratings). It is possible to realize about 100 gratings in this Transmission image detector (compared to 4 effective for the current Transmission image detector). The measurement signals are input for a processing device 49 which is arranged to determine third order distortions of the projection system (i.e. the lens) and/or of the patterning device. These third order distortions can be used to adjust the components of the lithographic apparatus, but they can also be used to improve alignment of the substrate table relative to the patterning device.

The Transmission image detector of Figure 4 further comprises a thin luminescent glass layer 43 that serves as a substrate for the litho layer 42 and converts DUV photons into visible light. A second function is to convert DUV light that enters with NA>1 into light that is emitted in all directions (including in the direction of the radiation sensitive sensors 46). Instead of luminescent glass layer, any other type of quantum conversion layer may be used. In this way each laser pulse of the illumination system IL can be detected individually by the Transmission image detector 40.

In a particular embodiment, the array of radiation sensitive sensors 46 is a 1-dimensional diode array. This diode array may be integrated on a substrate with photo diodes arranged in a row. In another embodiment, the array of radiation sensitive sensors 46 is a 1-dimensional CMOS camera. In yet another embodiment, the array of radiation sensitive sensors 46 is a 1-dimensional CCD camera. The Transmission image detector 40 uses a 1-dimensional camera with many pixels to do the sensing. A large number of gratings can be imaged simultaneously on such a camera.

In the embodiment of Figure 4, the Transmission image detector 40 comprises a fiber optics block 48 in between the gratings 41 and the respective radiation sensitive sensors 46. The thick (e.g. 5 mm) fiber optics block 48 serves as a stable substrate for the luminescent glass and transports the image formed in the luminescent glass to the camera. The fiber optics block can be as thick as fits in the mirror block, and provides the needed stiffness of the detector.

In an embodiment, the camera 46 is a high speed camera having a registration frequency of above 200 frames/second. If the camera 46 is a 1-D camera, it has only a limited number of pixels and such a high speed will not cause any data processing problems. One camera image may be taken for each laser pulse.

It should be noted that instead of the use of light sensitive sensors and a quantum conversion layer, it is possible to use a Transmission image detector having an array of sensors that are sensitive to DUV radiation. In that configuration the sensors will be positioned directly under the glass layer 43.

An example of a reticle that may be used in conjunction with the Transmission image detector as described above, is shown in Figure 5. The reticle 50 has an array of gratings just above and below an image field 52, see grating array 54 and grating array 56. As can be seen from Figure 5, the gratings are equally distributed over a significant range of the reticle 50.

It should be appreciated by the skilled person that other configurations are possible and that an equal distribution of the gratings is not a necessity. The reticle 50 at the position of the image field 52 will heat up due to absorption of radiation. The area outside the image field 52 will remain relatively cool. This will cause distortion and bending of the reticle 50. This distortion and bending cannot be measured with only two measurement positions in the field. The Transmission image detector according the invention can measure the distortion and bending of the reticle 50 with high accuracy due to the larger number of measurement points.

Figure 6 shows an example of an array of gratings in which X-gratings alternate with Y-gratings. The spacing and size of the gratings could for example be as shown in Figure 6, i.e. a pitch equal to 100 μm and a width of 20 μm.

The proposed Transmission image detector has several advantages over the existing Transmission image detectors. The proposed Transmission image detector has many (e.g. more than 100) gratings. Each grating gives a measurement result. Thus many results can be averaged and this will improve the reproducibility of a reticle align.

Furthermore, higher order distortions of the reticle or lens can be measured in detail. This will improve overlay.

Finally, one can select the gratings to be used to match the image field of a user. This will also improve overlay.

Instead of positioning arrays of gratings next to the image field 54, see Figure 5, it is also possible to position gratings in scribe lanes between the dies. This will give even more accurate measurement of the location of the image field, and thus leads to an improved overlay.

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

Although specific reference may have been made above to the use of embodiments of the invention in the context of optical lithography, it will be appreciated that the invention may be used in other applications, for example imprint lithography, and where the context allows, is not limited to optical lithography. In imprint lithography a topography in a patterning device defines the pattern created on a substrate. The topography of the patterning device may be pressed into a layer of resist supplied to the substrate whereupon the resist is cured by applying electromagnetic radiation, heat, pressure or a combination thereof. The patterning device is moved out of the resist leaving a pattern in it after the resist is cured.

The terms “radiation” and “beam” used herein encompass all types of electromagnetic radiation, including ultraviolet (UV) radiation (e.g. having a wavelength of or about 365, 355, 248, 193, 157 or 126 nm) and extreme ultra-violet (EUV) radiation (e.g. having a wavelength in the range of 5-20 nm), as well as particle beams, such as ion beams or electron beams.

The term “lens”, where the context allows, may refer to any one or combination of various types of optical components, including refractive, reflective, magnetic, electromagnetic and electrostatic optical components.

While specific embodiments of the invention have been described above, it will be appreciated that the invention may be practiced otherwise than as described. For example, the Transmission image detector may have a 2-dimensional camera, which will record radiation from a 2-dimensional array of gratings.

The descriptions above are intended to be illustrative, not limiting. Other aspects of the invention are set out as in the following numbered clauses.

1. A device for transmission image detection for use in a lithographic projection apparatus, said device comprising an array of gratings and an array of radiation sensitive sensors each of which is arranged to receive radiation coming through one of said gratings.

2. Device for transmission image detection according to clause 1, wherein said array of radiation sensitive sensors is a 1-dimensional diode array.

3. Device for transmission image detection according to clause 1, wherein said array of radiation sensitive sensors is a 1-dimensional CMOS camera.

4. Device for transmission image detection according to clause 1, wherein said array of

radiation sensitive sensors is a 1-dimensional CCD camera.

5. Device for transmission image detection according to clause 1, wherein said array of radiation sensitive sensors is a camera arranged to record images with a frequency of above 200 Hz.

6. Device for transmission image detection according to clause 1, wherein said device for transmission image detection comprises a quantum conversion layer on top of which said gratings are arranged.

7. Device for transmission image detection according to clause 6, wherein said device for transmission image detection comprises a fiber optics block in between said quantum conversion layer and said respective radiation sensitive sensors.

8. Device for transmission image detection according to clause 1, wherein said device comprises an array of more than 100 gratings and an array of more than 100 radiation sensitive sensors.

9. A lithographic apparatus comprising:
- an illumination system configured to condition a radiation beam;
- a patterning device being capable of imparting the radiation beam with a pattern in its cross-section to form a patterned radiation beam, said patterning device comprising an array of first gratings;
- a substrate table constructed to hold a substrate; and
- a projection system configured to project the patterned radiation beam onto a target portion of the substrate,
- a device for transmission image detection arranged on said substrate table, said device for transmission image detection comprising an array of second gratings and an array of radiation sensitive sensors each of which is arranged to receive radiation coming through

one of said first gratings and through one of said second gratings;
- a processing device arranged to calculate third order distortions of at least one of said patterning device and said projection system using signals received from said radiation sensitive sensors.

10. A method for determining third order distortions of at least one of a patterning device and a projection system of a lithographic apparatus, said method comprising:
- creating a radiation beam;
- imparting the radiation beam with a pattern in its cross-section to form a patterned radiation beam using a patterning device, said patterning device comprising an array of gratings;
- providing a device for transmission detection on said substrate, said device for transmission detection comprising an array of gratings and an array of radiation sensitive sensors arranged to receive radiation coming through said gratings and to produce measurement signals;
- sensing radiation coming through said gratings of said patterning device and through said gratings of said device for transmission detection;
- determining third order distortions of at least one of said patterning device and said projection system, using said measurement signals.

CONCLUSIE

1. Een lithografieinrichting omvattende:
een belichtinginrichting ingericht voor het leveren van een stralingsbundel;
een drager geconstrueerd voor het dragen van een patroneerinrichting, welke patroneerinrichting in staat is een patroon aan te brengen in een doorsnede van de stralingsbundel ter vorming van een gepatroneerde stralingsbundel;
een substraattafel geconstrueerd om een substraat te dragen; en
een projectieinrichting ingericht voor het projecteren van de gepatroneerde stralingsbundel op een doelgebied van het substraat, met het kenmerk, dat de substraattafel is ingericht voor het positioneren van het doelgebied van het substraat in een brandpuntsvlak van de projectieinrichting.

Fig 1

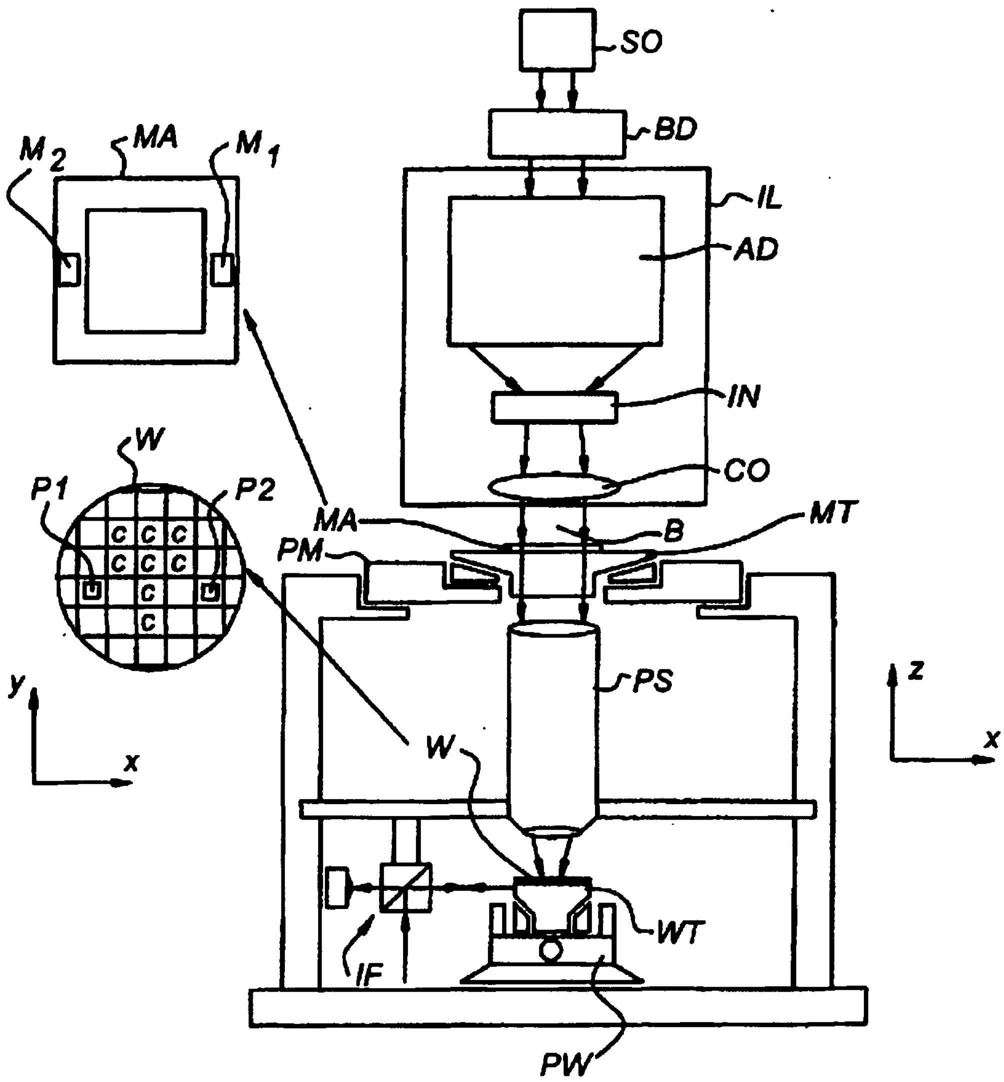


Fig 2

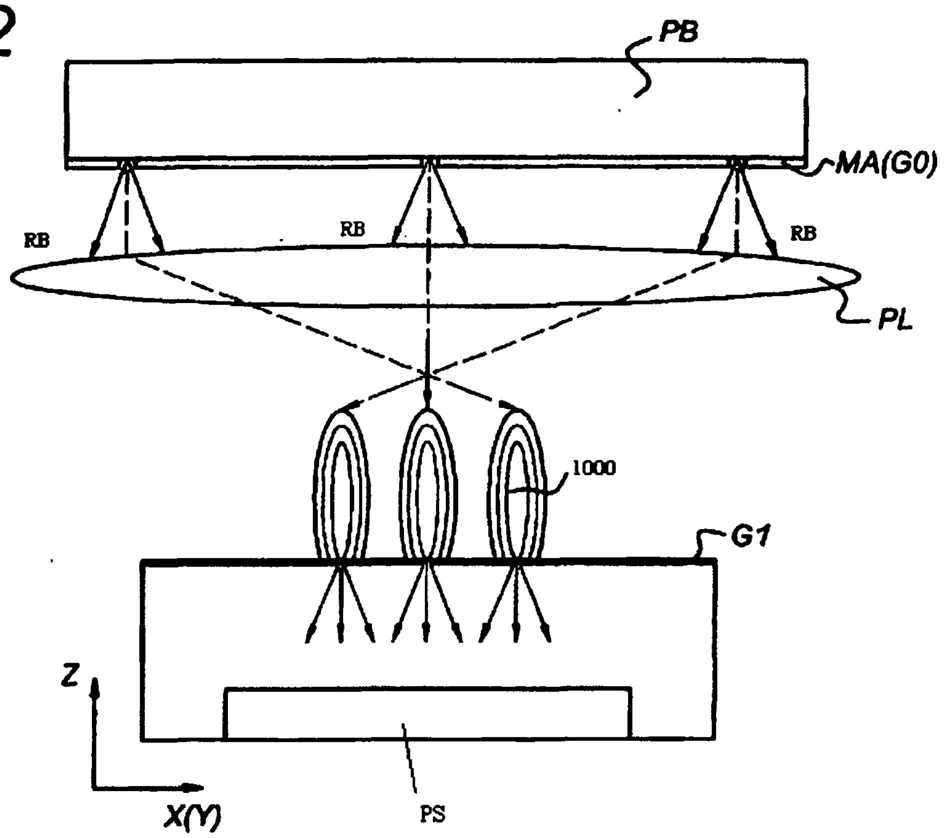

PB
MA(G0)
RB
RB
RB
PL
1000
G1
Z
X(Y)
PS

Fig 3

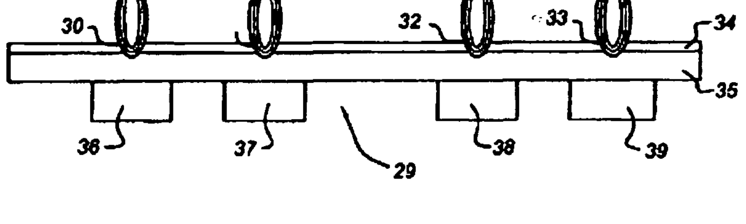

1000
1000
1000
1000
30
32
33
34
35
36
37
29
38
39

Fig 4

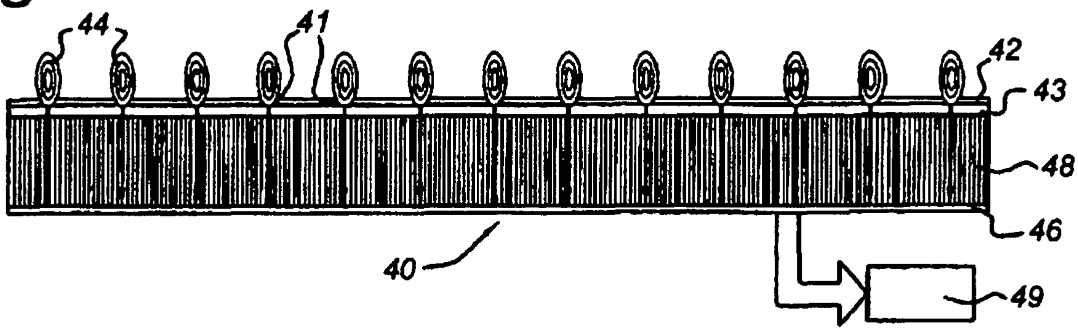
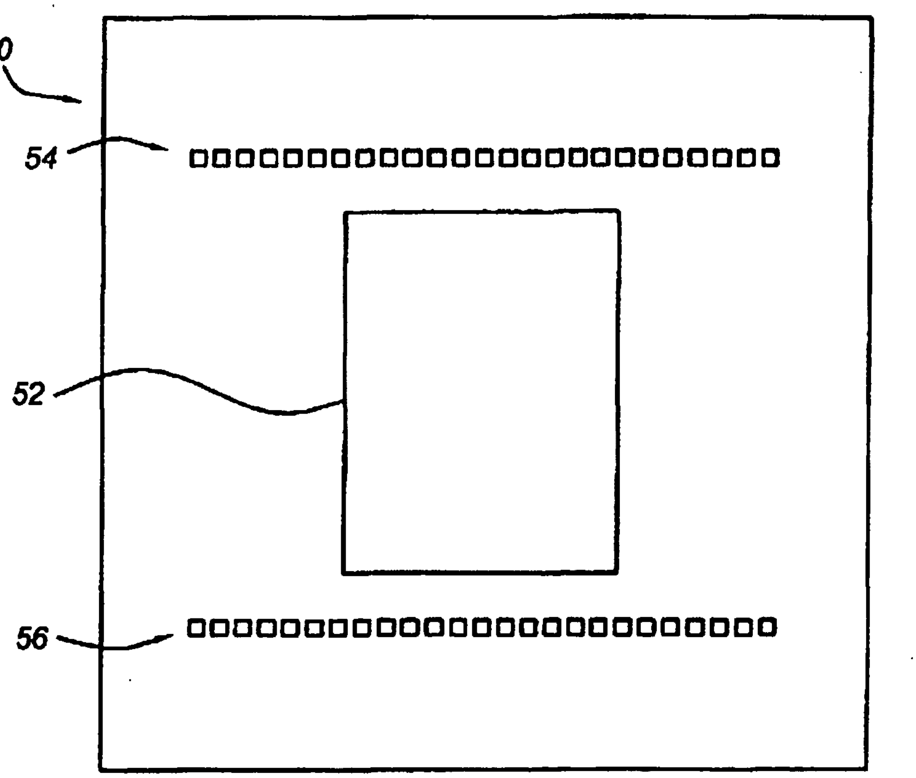


Fig 5



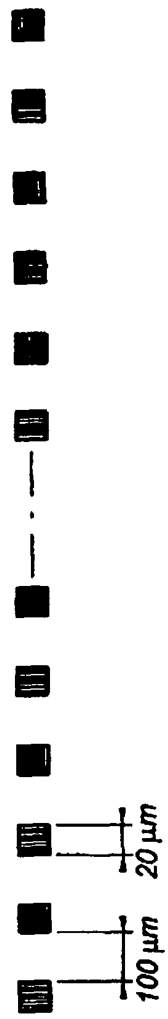


Fig 6

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