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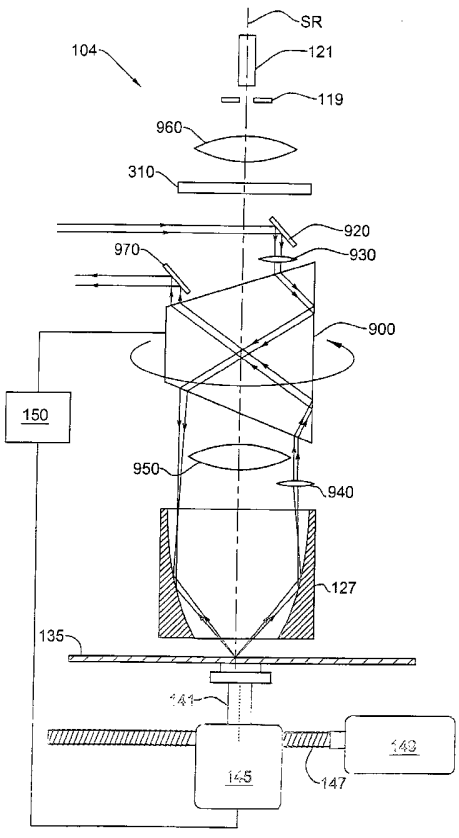
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(54) Title: APPARATUS AND METHOD FOR NON-DESTRUCTIVE INSPECTION ON A PATTERNED SURFACE



(57) Abstract: An optical system for detecting defects on a wafer (135) that includes a device for producing a beam and directing the beam onto the wafer surface, producing an illuminated spot on the wafer's surface. The system further includes a detector (121) detecting light, and a mirrored assembly (127) having together with the detector an axis of symmetry about a linen perpendicular to the wafer surface. The assembly is configured to receive scattered light from the surface, where the scattered light including a first scattered light part being scattered from the pattern. The assembly is further configured to reflect and focus rotationally symmetrically about the axis of symmetry the scattered light to the detector. The system further includes a device operating with the detector for facilitating detection of a scattered light other than the specified scattered light due to pattern.

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INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	**FOR FURTHER ACTION**	see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.
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This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 5 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language,** the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

   [ ] contained in the international application in written form.

   [ ] filed together with the international application in computer readable form.

   [ ] furnished subsequently to this Authority in written form.

   [ ] furnished subsequently to this Authority in computer readble form.

   [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

   [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title,**

   [ ] the text is approved as submitted by the applicant.

   [X] the text has been established by this Authority to read as follows:

   APPARATUS AND METHOD FOR NON-DESTRUCTIVE INSPECTION ON A PATTERNED SURFACE

5. With regard to the **abstract,**

   [ ] the text is approved as submitted by the applicant.

   [X] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 8c

   [ ] as suggested by the applicant.

   [X] because the applicant failed to suggest a figure.

   [ ] because this figure better characterizes the invention.

   [ ] None of the figures.

APPARATUS AND METHOD FOR NON-DESTRUCTIVE INSPECTION ON A PATTERNED SURFACE

FIELD OF THE INVENTION

The invention relates to the field of optical inspection. More specifically, the invention relates to the inspection of surfaces and in particular to detecting defects in semiconductor patterned wafers.

BACKGROUND OF THE INVENTION

The detection of defects on the surface of semiconductor wafers due to imperfect production or the post-production adhesion process has received considerable attention in the art. Generally, wafers fall into two main categories, "unstructured" (or "unpatterned") and "patterned". A patterned wafer has circuit patterns ("dies") imprinted on it, while an unstructured (unpatterned) wafer is still bare, i.e. with no circuits imprinted on it as yet.

Generally speaking, numerous systems and methods have been developed to cope with the problem of defect detection and in particular, for the non-destructive inspection of silicon wafers. A prior art system known as the "*Excite System*" of Applied Materials includes a light beam source and an optical system that projects the beam onto the test object, as well as means for detecting the reflected and/or scattered light. There is an additional assembly for moving the test object in a coordinated translational and rotary movement, so that the light spot projected thereon scans the whole surface along a spiral path. The detected scattered light is analyzed in order to determine the sought defects.

The development of processes enabling the manufacture of wafer surfaces with ever-finer structures, urged the development of inspection systems for the detection of ever more minute defects such as particle contamination, polishing scratches, variations in the thickness of coatings, roughness, crystal defects on and

below the surface, etc. Insofar as unstructured wafers are concerned, they are subjected to a thorough searching examination for detecting said defects.

In the chip manufacturing process, it is common to monitor each stage in order to recognize problems as early as possible and thus avoid undue waste. When unstructured wafers are compared between two process stages, the types and amount of defects at some stage can be determined. The inspected surface may be rough and metallized, and may therefore produce a great deal of scattered light, or, it may be a film-coated surface with a small amount of defects and produce scattered light. Thus, the inspecting instrument should preferably have a wide dynamic range of detection to permit defect and particle detection of a wide variety of surfaces.

Laser scanners are particularly suitable for that purpose. Note that presently available laser scanners differ in the type of scanning they use, their optical configuration, and the manner in which the results are processed. For applications that require a high throughput and nearly 100% inspection of the whole wafer surface, two processes are mainly used. In the first, disclosed e.g. in U.S. Pat. No. 4,314,763 to Steigmeier & Knop, the illuminating beam and the collecting optics are stationary, and the test object is scanned spirally by means of a coordinated translational and rotary movement of the object itself. In the second process disclosed, e.g. in U.S. Patent No. 4,378,159 to Galbraith, a rotating or vibrating mirror moves the illuminating beam in one direction linearly back and forth across the wafer, while the wafer is simultaneously translated perpendicular thereto. In general, the first method is simpler and with homogenous accuracy, while the second is faster.

Bearing all that in mind, attention is drawn to U.S. Patent No. 6,271,916 to Marxer et al. Briefly speaking, the Marxer patent discloses an assembly for non-destructive surface inspections. The system according to the '916 patent will now be briefly described with reference to Figs. 1A-B. Thus, the apparatus according to the Marxer patent includes a light beam that is directed by a beam deflector **131** towards the wafer's surface **135**, preferably normal thereto. The wafer is moved by

a rotation motor **145** and a translation motor **149** according to the technique disclosed in the '159 patent. A circumferential ellipsoidal mirrored surface **127** is placed around the wafer, with its axis coinciding with the surface normal, to collect scattered light from defects at the wafer surface at collection angles away from the surface normal. In some applications, a lens arrangement with its axis coinciding with the surface normal is also used to collect the light scattered by the surface and by any defects on it. The light scattered by the mirror and lenses may be directed to the same or different detectors. Preferably, light scattered by the surface within a first range of collection angles from the axis is detected by a first detector **121**, and light scattered by the surface within a second range of collection angles from the axis is detected by a second detector **125** (shown in Fig. 1B only). The two ranges of collection angles are different, with one detector optimized to detect scattering from large defects (mainly large particles) and the other detector optimized to detect light from small defects (particles). The content of the Marxer patent is incorporated herein by reference.

The detectors according to the Marxer patent, detect practically only light scattered from defects, whereas reflected light (reflected from a well-polished surface) is out-guided in order not to interfere with the scattered light received by the detectors. This method of measuring diffused light from defects only is called "dark field".

The apparatus according to the Marxer patent offers a solution applicable, if at all, to the detection of defects on unstructured wafers. However, the specified apparatus of the Marxer patent is not applicable to the detection of defects on patterned wafers, because in the case of patterned wafers, the detectors do not only receive light scattered from defects, but also light scattered from the patterns. Considering that the intensity of the latter is much higher than that of the former, it would be very difficult and in fact practically infeasible to determine whether the received light originates from a defect or from a fault-free pattern.

Die to die defect analysis is based upon a comparison (usually a on a pixel to pixel bases or even a sub-pixel to sub-pixel bases) of pixels originating from light

scattered from the same spot on two distinct dies. Die to die comparison require that substantially the same illumination and collection conditions apply during the generation of the pixels. The Marxer patent does not enable die to die defect analysis as the wafer is rotated during the illumination of the wafer, and both the illumination and collection paths constantly change as result from the wafers rotation. The problem is especially acute when the wafers are patterned and when using dark field detectors to detect defects, as the dark field images are very dependent upon the direction of light scattered from the rotating pattern.

Accordingly, there is a need in the art to provide an apparatus that performs defect detection of patterned wafers.

There is another need in the art to provide an apparatus that performs defect detection of both patterned and unpatterned wafers.

There is yet a further need to allow a compact optical inspection apparatus that enables die to die defect analysis.

SUMMARY OF THE INVENTION

The invention provides for an optical system for detecting defects on a wafer that includes at least one pattern; the system comprising:

a source of light to produce a beam;

optics directing the beam along a path onto the wafer, producing an illuminated spot thereon;

at least one detector for detecting light;

an ellipsoidal mirrored surface, said mirrored surface and the at least one detector having an axis of symmetry about a line perpendicular to the wafer surface, said mirrored surface defining an input aperture positioned proximate to the wafer surface to receive scattered light therethrough from the surface; said mirrored surface further defining an exit aperture and being substantially rotationally symmetric about said axis of symmetry, so that the mirrored surface reflects and focuses rotationally symmetrically about said axis of symmetry light that passes through the input aperture to the at least one detector;

said exit aperture being located opposite to the input aperture; and

at least one filter located between said exit aperture and said at least one detector and being configured to pass to said at least one detector scattered light rays substantially other than scattered light part being scattered from at least one of said patterns.

The invention enables die to die defect analysis by implementing at least one of the following measures: (i) illuminating the inspected object with a beam that is perpendicular to the surface of the inspected object, whereas the beam cross section is symmetrical and an array of detectors are positioned such as to collect scattered light beams ; (ii) using a dove prism; rotating the optical detectors array such as to compensate for the rotation of the wafer.

The invention further provides for an optical system for detecting defects on a wafer that includes at least one pattern; the system comprising:

a source of light to produce a beam;

optics directing the beam along a path onto the wafer surface, producing an illuminated spot thereon;

an array of detectors detecting light;

an ellipsoidal mirrored surface, said mirrored surface and the array of detectors having an axis of symmetry about a line perpendicular to the wafer, said mirrored surface defining an input aperture positioned proximate to the test surface to receive scattered light therethrough from the surface; said mirrored surface further defining an exit aperture and being substantially rotationally symmetric about said axis of symmetry, so that the mirrored surface reflects and focuses rotationally symmetrically about said axis of symmetry light that passes through the input aperture to the array of detectors;

said exit aperture being located between said array of detectors and said input aperture;

said array of detectors are adapted to detect scattered light substantially other than scattered light part being scattered from at least one of said patterns.

Still further, the invention provides for an optical system for detecting defects on a wafer that includes at least one pattern; the system comprising:

a source of light to produce a beam;

optics directing the beam along a path onto the wafer, producing an illuminated spot thereon;

at least one detector for detecting light;

an ellipsoidal mirrored surface, said mirrored surface and the at least one detector having an axis of symmetry about a line perpendicular to the wafer surface, said mirrored surface defining an input aperture positioned proximate to the wafer surface to receive scattered light therethrough from the surface; said mirrored surface further defining an exit aperture and being substantially rotationally symmetric about said axis of symmetry, so that the mirrored surface reflects and focuses rotationally symmetrically about said axis of symmetry light that passes through said input aperture to the at least one detector;

said exit aperture being located opposite to the input aperture;

a Dove prism, having with the at least one detector an axis of symmetry about a line perpendicular to the wafer's surface and parallel to said Dove prism's base, said Dove prism being rotated about said axis of symmetry, so as to rotate light passing through said Dove prism at twice the angular velocity of said Dove prism in the opposite direction about said axis of symmetry; and

at least one filter located between said Dove prism and said at least one detector and being configured to pass to said at least one detector scattered light rays substantially other than scattered light part being scattered from at least one of said patterns.

Yet further, an optical system for detecting defects on a wafer that includes at least one pattern; the system comprising:

a source of light to produce a beam;

optics directing the beam along a path onto the wafer, producing an illuminated spot thereon;

an array of detectors for detecting light;

an ellipsoidal mirrored surface, said mirrored surface and the array of detectors having an axis of symmetry about a line perpendicular to the wafer surface, said mirrored surface defining an input aperture positioned proximate to the wafer surface to receive scattered light therethrough from the surface; said mirrored surface further defining an exit aperture and being substantially rotationally symmetric about said axis of symmetry, so that said mirrored surface reflects and focuses rotationally symmetrically about said axis of symmetry light that passes through said input aperture to the array of detectors;

said exit aperture being located opposite to said input aperture;

a Dove prism, said Dove prism and the array of detectors having an axis of symmetry about a line perpendicular to the wafer surface and parallel to said Dove prism's base, said Dove prism being rotated about said axis of symmetry, so as to rotate light passing through said Dove prism at twice the angular velocity of said Dove prism in the opposite direction about said axis of symmetry; said Dove prism further being configured to pass to said array of detectors scattered light rays substantially other than scattered light part being scattered from at least one of said patterns.

The invention provides for an optical system for detecting defects on a wafer that includes at least one pattern; the system comprising:

a source of light to produce a beam;

means for directing the beam along a path onto the wafer, producing an illuminated spot thereon;

at least one means for detecting light;

an ellipsoidal mirrored surface, said mirrored surface and the at least one detecting means having an axis of symmetry about a line perpendicular to the wafer surface, said mirrored surface defining an input aperture positioned proximate to the wafer surface to receive scattered light therethrough from the surface; said mirrored surface further defining an exit aperture and being substantially rotationally symmetric about said axis of symmetry, so that the mirrored surface reflects and

focuses rotationally symmetrically about said axis of symmetry light that passes through the input aperture to the at least one detecting means;

said exit aperture being located opposite to the input aperture; and

at least one filter located between said exit aperture and said at least one detecting means and being configured to pass to said at least one detecting means scattered light rays substantially other than scattered light part being scattered from at least one of said patterns.

The invention further provides for an optical system for detecting defects on a wafer that includes at least one pattern; the system comprising:

a source of light to produce a beam;

means for directing the beam along a path onto the wafer surface, producing an illuminated spot thereon;

an array of detecting means for detecting light;

an ellipsoidal mirrored surface, said mirrored surface and the array of detecting means having an axis of symmetry about a line perpendicular to the wafer, said mirrored surface defining an input aperture positioned proximate to the test surface to receive scattered light therethrough from the surface; said mirrored surface further defining an exit aperture and being substantially rotationally symmetric about said axis of symmetry, so that the mirrored surface reflects and focuses rotationally symmetrically about said axis of symmetry light that passes through the input aperture to the array of detecting means;

said exit aperture being located between said array of detecting means and said input aperture;

said array of detecting means are adapted to detect scattered light substantially other than scattered light part being scattered from at least one of said patterns.

Still further, the invention provides for an optical system for detecting defects on a wafer, comprising:

a device for producing a beam and directing the beam onto the wafer surface, producing an illuminated spot thereon;

at least one detector detecting light;

a mirrored assembly having together with the at least one detector an axis of symmetry about a line perpendicular to the wafer surface, said assembly is configured to receive scattered light from the surface; said assembly further configured to reflect and focus rotationally symmetrically about said axis of symmetry the scattered light to the at least one detector; and

a device associated with said at least one detector for facilitating detection of a scattered light substantially other than scattered light part being scattered from at least one of said patterns.

Yet further, the invention provides for an optical system for detecting defects on a wafer, comprising:

a device for producing a beam and directing the beam onto the wafer surface, producing an illuminated spot thereon;

at least one detector detecting light;

a mirrored assembly configured to receive scattered light from the surface; said assembly further configured to reflect the scattered light to the at least one detector; and

a device associated with said at least one detector for facilitating detection of a scattered light substantially other than scattered light part being scattered from at least one of said patterns.

The invention provides for an optical method for detecting defects on a wafer that includes at least one pattern; the method comprising:

providing a beam of light;

directing the beam along a path onto the wafer, producing an illuminated spot thereon;

positioning an ellipsoidal mirrored surface and at least one detector so that they have an axis of symmetry about a line perpendicular to the wafer surface, said mirrored surface defining an input aperture positioned proximate to the wafer surface to receive scattered light therethrough from the surface; said mirrored surface further defining an exit aperture and being substantially

rotationally symmetric about said axis of symmetry, so that the mirrored surface reflects and focuses rotationally symmetrically about said axis of symmetry light that passes through the input aperture to the at least one detector; said exit aperture being located opposite to the input aperture; and

locating at least one filter between said exit aperture and said at least one detector, configuring the at least one filter to pass to said at least one detector scattered light rays substantially other than scattered light part being scattered from at least one of said patterns.

Still further, the invention provides for An optical method for detecting defects on a wafer that includes at least one pattern; the method comprising:

providing a beam of light;

directing the beam along a path onto the wafer surface, producing an illuminated spot thereon;

positioning an ellipsoidal mirrored surface and an array of detectors so that they have an axis of symmetry about a line perpendicular to the wafer, said mirrored surface defining an input aperture positioned proximate to the test surface to receive scattered light therethrough from the surface; said mirrored surface further defining an exit aperture and being substantially rotationally symmetric about said axis of symmetry, so that the mirrored surface reflects and focuses rotationally symmetrically about said axis of symmetry light that passes through the input aperture to the array of detectors; said exit aperture being located between said array of detectors and said input aperture;

adapting said array of detectors to detect scattered light substantially other than scattered light part being scattered from at least one of said patterns.

Yet further, the invention provides for an optical method for detecting defects on a wafer that includes at least one pattern; the method comprising:

providing a beam of light;

directing the beam along a path onto the wafer, producing an illuminated spot thereon;

positioning an ellipsoidal mirrored surface and at least one detector so that they have an axis of symmetry about a line perpendicular to the wafer surface, said mirrored surface defining an input aperture positioned proximate to the wafer surface to receive scattered light therethrough from the surface; said mirrored surface further defining an exit aperture and being substantially rotationally symmetric about said axis of symmetry, so that the mirrored surface reflects and focuses rotationally symmetrically about said axis of symmetry light that passes through said input aperture to the at least one detector; said exit aperture being located opposite to the input aperture;

positioning a Dove prism, so as to have with the at least one detector an axis of symmetry about a line perpendicular to the wafer's surface and parallel to said Dove prism's base; said Dove prism is rotated about said axis of symmetry, so as to rotate light passing through said Dove prism at twice the angular velocity of said Dove prism in the opposite direction about said axis of symmetry; and

locating at least one filter between said Dove prism and said at least one detector and configuring the filter to pass to said at least one detector scattered light rays substantially other than scattered light part being scattered from at least one of said patterns.

The invention provides for an optical method for detecting defects on a wafer that includes at least one pattern; the method comprising:

providing a beam of light;

directing the beam along a path onto the wafer, producing an illuminated spot thereon;

positioning an ellipsoidal mirrored surface and an array of detectors so that they have an axis of symmetry about a line perpendicular to the wafer surface, said mirrored surface defining an input aperture positioned proximate to the wafer surface to receive scattered light therethrough from the surface; said mirrored surface further defining an exit aperture and being substantially rotationally symmetric about said axis of symmetry, so that said mirrored surface reflects and focuses rotationally symmetrically about said axis of

symmetry light that passes through said input aperture to the array of detectors; said exit aperture being located opposite to said input aperture;

positioning a Dove prism so as to have with the array of detectors an axis of symmetry about a line perpendicular to the wafer surface and parallel to said Dove prism's base; said Dove prism is rotated about said axis of symmetry, so as to rotate light passing through said Dove prism at twice the angular velocity of said Dove prism in the opposite direction about said axis of symmetry; said Dove prism is further being configured to pass to said array of detectors scattered light rays substantially other than scattered light part being scattered from at least one of said patterns.

The invention further provides for an optical method for detecting defects on a wafer, comprising:

providing a device for producing a beam and directing the beam onto the wafer surface so as to produce illuminated spot thereon;

positioning a mirrored assembly and at least one detector so that they have an axis of symmetry about a line perpendicular to the wafer surface; configuring said assembly to receive scattered light from the surface and further configuring said assembly to reflect and focus rotationally symmetrically about said axis of symmetry the scattered light to the at least one detector; and

positioning a device associated with said at least one detector for facilitating detection of a scattered light substantially other than scattered light part being scattered from at least one of said patterns.

Yet further, the invention provides for an optical method for detecting defects on a wafer, comprising:

providing a device for producing a beam and directing the beam onto the wafer surface so as to produce an illuminated spot thereon;

positioning a mirrored assembly configured to receive scattered light from the surface and further configuring said assembly to reflect the scattered light to the at least one detector; and

positioning a device associated with said at least one detector for facilitating detection of a scattered light substantially other than scattered light part being scattered from at least one of said patterns.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to understand the invention and to see how it may be carried out in practice, a preferred embodiment will now be described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

Fig. 1A-B illustrate schematically two embodiments of an apparatus according to the Marxer patent;

Fig. 2A shows a perspective view of an apparatus according to one embodiment of the present invention;

Fig. 2B shows a perspective view of an apparatus according to another embodiment of the present invention;

Fig. 2C shows a perspective view of an apparatus according to still another embodiment of the present invention;

Fig. 3A shows a perspective view of a filter placed in the apparatus according to an embodiment of the present invention;

Figs. 3B-C describe the rotation of the filter synchronized with the wafer's rotation, in accordance with an embodiment of the invention;

Figs. 4A-B show a side view of a closed and open MEMS (Micro-Electro-Mechanical System), in accordance with an embodiment of the invention;

Fig. 4C shows a plan view of the MEMS illustrated in Figs. 5A and 5B;

Fig. 4D shows a filter comprised of a 2D matrix of MEMS, in accordance with an embodiment of the invention;

Figs. 5A-B illustrate two stages (pass/fail) of a liquid crystal based filter in accordance with an embodiment of the invention;

Fig. 5C shows a filter that is composed of 2D matrix liquid crystal cells, in accordance with an embodiment of the invention;

Fig. 6A shows a ring-shaped array of detectors, in accordance with an embodiment of the invention;

Fig. 6B shows concentric ring-shaped arrays of detectors, in accordance with an embodiment of the invention;

Fig. 7 A shows a perspective view of an array of detectors made of CCDs, in accordance with an embodiment of the invention;

Figs. 7B-C show respective opening and closing of CCDs according to wafer rotation, in accordance with the embodiment of Fig. 8A;

Fig. 8A illustrates the principle of operation of a Dove prism;

Fig. 8B further exemplifies the rotation of an image due to rotation of a Dove prism; and

Figs. 8C and 8D show perspective views of an apparatus according to still another embodiment of the present invention, using a Dove prism between minor to detector.

DETAILED DESCRIPTION OF THE INVENTION

It should be noted that in the context of the invention, the term "defect" should be construed in a broad manner including but not limited to particle contamination, polishing scratches, variations in the thickness of coatings, roughness, crystal defects on and below the surface etc.

A beam of light that impinges on the surface of a patterned wafer produces a reflected beam and multiple scattered rays due to pattern and due to (possible) defects. The distribution of scattered rays due to pattern is distributed substantially different than the distribution of scattered ray due to defects. Thus, knowing in advance the distribution of scattered rays due to pattern, enables one to locate a set of detectors at places where the distribution of scattered rays due to pattern is zero, or at least minimal, or alternatively block the light rays at places where the distribution of rays due to pattern is significant, and by this to detect mainly

scattered rays due to defects. This method can be used to verify the presence of defects on a patterned wafer, as will be explained in detail below.

Fig. 2A shows apparatus **101** according to an embodiment of the present invention. The apparatus differs from that described in U.S. Pat. No. 6,271,916 B1, in that it is operable to detect defects of patterned wafers. Apparatus **200** includes filter **310** that is disposed between an ellipsoidal mirror **127** and a detector **121**. The added filter is designed to block the path of scattered light due to the pattern, but simultaneously let the scattered light due to a defect pass through, as will be explained in greater detail below.

Fig. 2B shows apparatus **102** in accordance with another embodiment of the invention. Apparatus **102** is similar to apparatus **101,** but has multiple detectors, such as detector array **320**, instead of filter **310**.

Fig. 2C shows apparatus **103** in accordance with a further embodiment of the invention. Apparatus **103** is similar to apparatus **101** but has additional multiple detectors, such as detector array **320** located upstream in the paths of scattered and reflected light beams in relation to filter **310**. The addition of these detectors enables to geometrically select the pattern of scattered light-rays to be detected, which improves the system's performance.

Note that although the light beam that impinges the wafer surface in the examples of Figs. 2A and 2B is perpendicular to the surface, the invention is by no means bound by these specific embodiments, as exemplified in Fig. 2C. An exemplary embodiment where the light impinges the surface in a non-perpendicular fashion is described with reference to Fig. 8C-D, below.

Further note that whereas for the convenience of explanation the description below concerns mainly a filter, it likewise applies to an array of filters.

It also should be noted that the invention is by no means bound by this specific embodiment. Thus, for example, in accordance with a modified embodiment, any of the previous embodiments can be modified, e.g. to include a first optical means that collimate the scattered light to be filtered and second optical means to focus the filtered beam before impinging on the detector. The first optical

means can be used also for matching the diameter of the collimated beam to the diameter of the filter **310** or to the diameter of the detector array **320**. Both optical means can be used also for fine-tuning the solid angle of the beam of light impinging on the filter and/or the detector. In still another modified embodiment a lens assembly is disposed between the input aperture and the exit aperture of ellipsoidal mirrored surface **127** to collect light reflected from the wafer surface and passing through the mirrored surface. The reflected light is then guided away from the filter to be blocked or used for further detection.

Generally speaking, when the wafer rotates, different dies on the wafer are exposed to the illumination spot for inspection purposes. Since all dies in the wafer have the same orientation, it readily arises that as the wafer rotates, the inspected die's pattern is oriented at a different angle for each rotation. Accordingly, by the embodiments of Figs. 2A-2C, whichever the case may be, the filter **310** and/or detectors **320** should be rotated or reconfigured in synchronization with that of the wafer rotation such that the filter will substantially block the scattered light due to the pattern and, by the same token, the detectors will be substantially blocked from detection of the scattered light due to the pattern. In contrast, the filter should substantially pass scattered light due to defect(s) and by the same token, the detectors should substantially detect light due to defect(s). By "substantially" it is meant that not all scattered light due to defect(s) is passed or detected, which the case may be. To this end, a controller **150** is utilized, as will be explained in greater detail below.

There are several ways to realize the above described process, as will now be explained with reference to Fig. 3 and onwards. As shown in Fig. 3A, apparatus **101** has filter **310** that includes disk **401,** which is opaque to light. In the disk **401** there are apertures **403** at pre-defined locations such that scattered light due to defects can pass through said filter only through said apertures. A controller **150** that is coupled to both the disk **401** and rotation motor **143** is configured to rotate the disk about the axis of symmetry SR in a synchronized fashion with said motor, so as to let the light scattered from the defects pass through said apertures and be

detected by the detector **121**. The scattered light (or major portion thereof) due to the pattern, impinges on the opaque sectors **401** and is blocked thereby, and consequently, will not reach detector **121** and obviously will not be detected. Thus, the filter functions as a rigid mask to substantially block all scattered light rays due to the pattern in accordance with the (same) rotational movement of all the detectors.

It should be noted that, as known per se, the shape of the filter (e.g. in the form of disk), and in particular the pattern of apertures such as **403**, is tailored to fit the pattern of the surface. Such filters are known in the art. Such a disk may be either designed e.g. in accordance with actual measurements of the distribution of light reflection due to pattern, or as a consequence of a mathematical model describing the reflection and scattering pattern from a specific wafer.

Further note that a filter bank can be prepared in advance for a variety of requirements. A filter assembly composed of several filters (e.g. in the form of a large disk that contains several filters along its perimeter) can be used as filter **403**. For each type of patterned wafer, the most suitable filter on the filter assembly is chosen in accordance with actual measurements of the distribution of light reflection due to pattern received at the detector after being reflected by a each filter available on the assembly and selecting the most appropriate one.

The filter ensures that the scattered light rays that reach the detectors are mainly or wholly due to defects. The rotation of the filter is exemplified in Fig. 3B-C.

Those versed in the art will readily appreciate that the invention is not bound by the use of a disk with discrete apertures and particularly not to the disk described in Figs. 3A-C.

Another non-limiting realization of a filter is the Micro-Electro-Mechanical System (MEMS) 2D array technique shown in Fig. 4A-D. The MEMS array-of-shutters functions exactly as a filter described above with reference to Figs. 3A-C, except for the fact that the rotation is done electronically. Thus, Fig. 4A schematically describes the structure of a rectangular MEMS shutter. It is noted that

other shaped MEMS arrays, such as circular MEMS arrays may be utilized. MEMS arrays are known in the art. Fig. 4A-D illustrate a typical MEMS array. The etching of a thick silicon wafer bedding **500** produces a thin sheet of silicon **505** that is partially surrounded by a narrow spacing **507** and is also connected to a thick sheet of silicon **503**. The narrow spacing **507** is generated by etching the whole silicon thick layer. Therefore, the thin sheet **505** is able to bend to some degree. The addition of electrodes **509** enables to realize the bending of the thin silicon sheet (Fig. 4B) or aligning it back (Fig. 4A), thus giving rise to an opening or closing of the shutter. The MEMS technique enables to produce a 2D array of, say, hundreds of shutters, a number large enough to make an effective filter for the purpose of the present invention, as shown schematically in Fig. 4D.

In order to block scattered light due to a die pattern, some of the shutters should be closed in a pattern that fits the pattern of said scattered light, i.e. scattered light due to the pattern should be blocked (by impinging on closed shutters) and scattered light due to defects should pass through open shutters, similar to the configuration described above, with reference to Fig. 3A. To this end, a controller of the kind described above should be employed to synchronize between the wafer rotation and the opening/closing of the MEMS shutters.

Those versed in the art will readily appreciate that the invention is not bound by the use of an array of shutters and particularly not to the MEMS array described in Figs. 4A-D.

Another non-limiting realization of a filter is the Liquid Crystal Display (LCD) technique, presented in Figs. 5A-C. As is generally known *per se*, LCD unit (or cell) is a device having a first polarizer and a second polarizer, both defining a space in which a liquid crystal is placed. A liquid crystal is fluid like a regular liquid but is anisotropic in its optical and electromagnetic characteristics like a solid, due to the high orientational order of the liquid crystal molecules (**620** in Fig. 5A).

When plane-polarized light passes through a liquid crystal, the molecules of the liquid crystal rotate the plane of polarization of the light. Light that passes

through the first polarizer **640** is polarized. The polarized light passes then through the liquid crystal, which rotates the plane of polarization of the passing light. The second polarizer **660** is placed at the exit of the liquid crystal. The orientation of the second polarizer is chosen to be parallel to the polarization of the light emanating from the liquid crystal (e.g. perpendicular to first polarizer, but in no case parallel to it). Thus, the liquid crystal guides the polarized light from the first polarizer so that the light may be transmitted through the second polarizer.

When an external voltage **610** is applied across a liquid crystal cell, the liquid crystal molecules (**630** in Fig. 5B) are aligned in parallel to the electric field that is induced by the external voltage, and cannot rotate the plane of polarization of the passing light anymore. Thus, light cannot get out of the device any more. Therefore, applying a voltage on the LCD based device **601** in Fig. 5B blocks the light in analogy to the functioning of the MEMS device. The LCD 2D array in Fig. 5C functions similarly to the 2D MEMS array explained above, where voltage activated (open) MEMS is functionally analog to a non-activated (open) LCD cell **600** and close MEMS is functionally analog to a voltage activated (close) LCD cell **601**. The device uses a controller of the kind specified above to synchronize between the opening/closing of LCD shutters and the wafer rotation.

Those versed in the art will readily appreciate that the invention is not bound by the use of an array of shutters and particularly not to the liquid crystal array described in Figs. 5A-C.

Note that the blocking of scattered light due to the die's pattern can be realized also by using an array of detectors. The array of detectors is adapted to detect scattered light substantially other than said scattered light due to a pattern. By one embodiment, this is realized in a way that the detectors in the array are switched on or off via a controller in a synchronized manner to the rotation of the wafer as in the case of a filter described with reference to Fig. 2A above. By way of another example, this may be realized by switching on all the detectors but reading under the control of the controller only data indicative of scattered light substantially other than said scattered light due to pattern

Note that each detector has its own light collection zone. The light collection zones of different detectors may vary in shape, in size and/or in their direction. The light collection zones of neighboring detectors preferably partially overlap, so as to ensure coverage of the whole detection area.

There may be many realizations that utilize an array of detectors. There follows a description of two non-limiting embodiments.

In accordance with a first realization described with reference to Fig. 6A, detector array **320** includes a plurality of detectors collectively denoted **700** that are arranged in a ring shape. Such a device may include e.g. several tens of detectors, such as detectors **701** (e.g. Photo-multiplier Tubes (PMTs), Photodiodes, Avalanche Photodiodes), which is enough for obtaining considerable (but still rough) sensitivity to the rotation of dies.

Detector array **320** may also include multiple detectors arranged as a few concentric rings, as illustrated at Fig. 6B. All the ringed arrays of detectors are concentrically placed at one plane and oriented towards the same location. This configuration enables to add more detectors and improves the configuration's sensitivity to the angular orientation of the die.

Those versed in the art will readily appreciate that the invention is not bound by the use of ringed arrays of detectors and particularly not to the array of detectors described in Figs. 6A or 6B.

Another realization is shown in Figs. 7A-C. Figure 7A illustrates apparatus **102** in which detector array **320** includes a CCD array. A CCD array **800** is an array of light-sensitive elements **802**, which are, in fact, some small electronic capacitors that are charged by the electrons that are generated by incident light. The array may be implemented by at least one CCD chip, each CCD chip including multiple CCD detecting elements. Common CCD chips are composed of a large number of detecting elements, referred to also as *pixels* (e.g. 192*165, 512*512, 1024*1024 or more). Thus, the use of a CCD array is advantageous as compared to an array of regular detectors, in that the number of detectors (i.e. cells) is enormously higher

than in the former realization. This makes the CCD array much more accurate and sensitive to small angle rotations.

The main disadvantage of using a CCD array is the huge data rate delivered as an output of the CCD. The sampling rate of dies on a wafer is very high, typically, although not necessarily, about 10^7 samples/sec. Thus, the data rate that should be delivered from a CCD is about $N*10^7$ pixels/sec, where N is the number of CCD elements. Since a typical CCD has about 10^4-10^6 pixels, the expected output data rate is in the range of 10^{11}-10^{13} pixels /sec, which is well beyond the present technology. An example for a fast CCD array is the PB-MV40 Megapixel CMOS Image Sensor of Photobit Company, which is capable of a digital output of almost 10^9 pixels /sec per second, at most one percent of the expected rate.

A non-limiting solution to the problem of the data-processing bottleneck is by reading only a partial set of elements at each sampling (e.g. **802**, not **804**), since, anyway, not all of them are required for collecting scattered light from defects. Note that a CCD array composed of a large number of CCD chips, each chip having its own light collection zone, can be partitioned so as to allow such a selection, by avoiding data collection from chips that get scattered light due to pattern. Still, the amount of information is huge, rendering the data processing relatively complicated.

Those versed in the art will readily appreciate that the invention is not bound by the use of a CCD array and particularly not to the CCD array described in Figs. 7A-C.

Reverting now to Fig. 2C, it is possible to use both a filter and an array of detectors. This combination adds a degree of freedom to geometrically select the pattern of scattered light-rays to be detected. This choice can improve the system's performance.

Another way to realize the apparatus according to the present invention, is by rotating the beam of scattered light at the outlet of the mirror **127**, instead of rotating a filter or detector-array for the same purpose. This can be realized by using a Dove prism, whose principle of operation is schematically shown in Fig.

8A. A Dove prism is a prism whose triangular head is truncated. When light rays enter an incidental wall **901** of Dove prism **900**, they get out of the other wall **902** in a reversed order. When the Dove prism **900** is rotated around an axis **DP** parallel to its base, as is shown in Fig. 8B, the entering image is rotated too at twice the angular velocity of the prism. This is illustrated in Fig. 8B, where the image **910** is rotated by 180° with reference to the object **905**, as compared to a 90° rotation of Dove prism **900**. Note that while rotating Dove prism **900** the field of view (e.g. an image **910** of a die on the wafer) is rotated too, but the latter does not change its location within the wafer's surface. Thus, using Dove prism **900** obviates the need to rotate the filter in a controlled fashion or to control the detector array as discussed above.

The use of a dove prism 900 allows performing die to die defect analysis, as the dove prism rotation compensates for the wafers rotation. In other words, the dove prism provides substantially the same illumination and collection conditions, regardless the rotation of the wafer. An image of a die can be stored to be later compared to an image of another die or a to a golden die.

Figs. 8C and 8D illustrate apparatus **104**, in accordance with a preferred embodiment of the invention. Apparatus **104** differs from apparatus **101** of Fig. 2A by setting Dove prism **900** disposed between the exit aperture of ellipsoidal mirror **127** and filter **310**. In addition, lens assembly **930** is set for focusing the light beam onto the wafer surface and lens assembly **940** for collimating the reflected beam at the outlet of ellipsoidal mirror **127**. Lens assembly **950** is set for collimating the light rays scattered from the wafer surface due to pattern and defects, while lens assembly **960** is set to focus the light at the outlet of filter **320** on detector **121.** Note that lens assembly **950** is needed only when filter **310** is used for apparatus **104,** but not in the alternative where detector array **320** is used. Note that controller **150** is required for rotating Dove prism **900** in a controlled fashion with the wafer rotation to compensate for the rotation of wafer pattern, as explained above.

Thus, according to one embodiment of the present invention, schematically illustrated in Figs. 8C and 8D, Dove prism **900** is rotated at half the angular

velocity of the wafer rotation in the opposite direction. The image at the exit of the Dove prism is a static image of a die, since the prism rotation compensates for the wafer rotation. The filter e.g. **310** or detectors array e.g. **320** as described above are placed at the exit of the Dove prism.

Fig. 8C describes the path of the bright-field light beam in the system. A beam of light is guided by mirror **920** to lens **320** that focuses the beam. The beam is guided through Dove prism **900** and the ellipsoidal mirror **127** onto the wafer surface. Lens **930** may be located also between Dove prism **900** and ellipsoidal mirror **127**, on the condition that it has a ring shape, to allow the path of scattered rays upstream. The reflected beam is guided back through ellipsoidal mirror **127** to lens **940** that collimates the beam. The collimated beam passes through Dove prism **900** and is guided away by mirror **970** to be blocked or for further detection for other applications.

Fig. 8D describes the dark-field light beam in the system, showing the path through the optical system of the scattered rays due to pattern and defects. Lens assembly **950** and **960** form a *relay assembly*, which is intended to image the plane proximate to the wafer surface at a remote plane where the detector or detector array are located. Note that the detector (detectors array) are disposed relatively away from the surface (requiring thus the image at the remote plane) due to the relatively large size of the Dove prism. Relay assembly **950** and **960** enable to detect the image as if it were closer to the wafer. Lens assembly further matches the diameter of the collimated beam to the diameter of filter **310**. The scattered light rays are collimated by lens assembly **950** to be guided through Dove prism **900**. At the outlet of the Dove prism the collimated beam passes through filter **310** and then is focused by lens assembly **960** to impinge onto detector **121**.

Note that other embodiments of Dove Prism are applicable. For example, instead of using filter **310** and detector **121**, detectors array **320** is used. In still another embodiment of the present invention, filter **310** and detectors array **320** are used. The latter modifications are substantially similar to those described with reference **101-103** in Figs. 2A-C.

Further note that the embodiment of apparatus **104** has two advantages over the embodiments of apparatuses **101-103** illustrated with reference to Figs. 2A-C. First, the image at the outlet of the Dove prism is static independent of the die's orientation. This means that the filter or the detector array gets practically the same distribution of light rays for each die. On the contrary, for the embodiments **101-103** the filter should be rotated in a controlled fashion (or the detector array operated in a controlled fashion) so as to match the image rotation. Thus, in the embodiments **101-103** unavoidable errors occur due to the limited resolution of the filter or of the detector array. The second advantage is that apparatus **104** is better adapted to use asymmetric light source, i.e. light source directed at a first angle in relation to the normal to the wafer surface (where the normal constitutes symmetry axis **SR**). For all the embodiments of Figs. 2A-C, the use of an asymmetric light source necessarily entails the rotation of the light source in a synchronized fashion with the wafer rotation, thus maintaining the same orientation with the pattern of each die. Otherwise the filter or detector array would receive a totally different distribution of scattered light due to the pattern for each die. In contrast, in apparatus **104**, as was explained above, the resulting image at the filter or detector array is static, due to the Dove prism, and therefore there is no need to rotate the light source.

Those versed in the art will readily appreciate that the invention is not bound by the use of a rotating prism and particularly not to the Dove prism described in Figs. 8A-C.

The invention has been described with a certain degree of particularity. Those versed in the art will readily appreciate that the invention is not bound by the particular configurations described with reference to Figs. 2 to 8 above or by the specific apparatus disclosed in the Marxer patent.

CLAIMS:

1) An optical system for detecting defects on a wafer that includes at least one pattern; the system comprising:

a source of light to produce a beam;

optics directing the beam along a path onto the wafer, producing an illuminated spot thereon;

at least one detector for detecting light;

an ellipsoidal mirrored surface, said mirrored surface and the at least one detector having an axis of symmetry about a line perpendicular to the wafer surface, said mirrored surface defining an input aperture positioned proximate to the wafer surface to receive scattered light therethrough from the surface; said mirrored surface further defining an exit aperture and being substantially rotationally symmetric about said axis of symmetry, so that the mirrored surface reflects and focuses rotationally symmetrically about said axis of symmetry light that passes through the input aperture to the at least one detector; said exit aperture being located opposite to the input aperture; and

at least one filter located between said exit aperture and said at least one detector and being configured to pass to said at least one detector scattered light rays substantially other than scattered light part being scattered from at least one of said patterns.

2) The optical system of Claim **1,** wherein the at least one filter comprises a disk with apertures at pre-defined locations and being rotated, under a control of a controller, about said axis of symmetry; said controller is configured to rotate said filter so as to pass to the at least one detector, through said apertures, scattered light rays substantially other than said scattered light part to be detected by the at least one detector.

3) The optical system of Claim **1,** wherein the at least one filter comprises a Micro-Electro-Mechanical System (MEMS).

4) The optical system of Claim **1,** wherein the at least one filter comprises a Liquid Crystal Display (LCD) composed of LCD cells.

5) The optical system of Claim **1,** further comprising a lens assembly disposed between the input aperture and the exit aperture to collect light passing through the input aperture, defining collected light, said lens assembly focusing the collected light substantially at the at least one detector, said at least one detector providing output in response to the light focused to it by the mirrored surface and the lens assembly.

6) The optical system of Claim **1,** further comprising first lens assembly disposed between said exit aperture and said at least one filter, said first lens assembly collimating the light passing through said exit aperture, so that light passing through said at least one filter is perpendicular to at least one filter's surface and second lens assembly between said at least one filter and at least one detector, said second lens assembly focusing the light passing through said at least one filter substantially at the at least one detector.

7) An optical system for detecting defects on a wafer that includes at least one pattern; the system comprising:

a source of light to produce a beam;

optics directing the beam along a path onto the wafer surface, producing an illuminated spot thereon;

an array of detectors detecting light;

an ellipsoidal mirrored surface, said mirrored surface and the array of detectors having an axis of symmetry about a line perpendicular to the wafer, said mirrored surface defining an input aperture positioned proximate to the

test surface to receive scattered light therethrough from the surface; said mirrored surface further defining an exit aperture and being substantially rotationally symmetric about said axis of symmetry, so that the mirrored surface reflects and focuses rotationally symmetrically about said axis of symmetry light that passes through the input aperture to the array of detectors;

said exit aperture being located between said array of detectors and said input aperture;

said array of detectors are adapted to detect scattered light substantially other than scattered light part being scattered from at least one of said patterns.

8) The optical system of Claim **7**, wherein the array of detectors comprises at least one annular array of detectors that are oriented to detect light from distinct directions and a controller configured to enable or disable reading data from each one of said detectors so as to detect scattered light substantially other than said scattered light part being scattered from at least one of said patterns.

9) The optical system of Claim **8**, wherein said array of detectors includes at least two concentric annular arrays of detectors and a controller configured to enable or disable reading data from each one of said detectors so as to detect scattered light substantially other than said scattered light part being scattered from at least one of said patterns.

10) The optical system of Claim **7**, wherein the array of detectors comprises a CCD array of pixels producing pixel values in response to light incident on the CCD array and means for reading, during each sampling, selected pixel values so as to detect scattered light substantially other than said scattered light part being scattered from at least one of said patterns.

11) The optical system of Claim **10**, wherein the CCD array comprises multiple CCD sub-arrays and a controller configured to enable reading data from part of said sub-arrays so as to detect scattered light substantially other than said scattered light part being scattered from at least one of said patterns.

12) The optical system of Claim **7**, further comprising a lens assembly disposed between the input aperture and the exit aperture to collect light passing through the input aperture, defining collected light, said lens assembly focusing the collected light substantially at said array of detectors; said array of detectors providing output in response to the light focused to it by the mirrored surface and the lens assembly.

13) The optical system of Claim **7**, further comprising a lens assembly between said exit aperture and said array of detectors, said lens assembly collimating the light passing through said exit aperture, so that light passing through said filter is perpendicular to the surface of the array of detectors.

14) An optical system for detecting defects on a wafer that includes at least one pattern; the system comprising:

a source of light to produce a beam;

optics directing the beam along a path onto the wafer, producing an illuminated spot thereon;

at least one detector for detecting light;

an ellipsoidal mirrored surface, said mirrored surface and the at least one detector having an axis of symmetry about a line perpendicular to the wafer surface, said mirrored surface defining an input aperture positioned proximate to the wafer surface to receive scattered light therethrough from the surface; said mirrored surface further defining an exit aperture and being substantially rotationally symmetric about said axis of symmetry, so that the mirrored surface reflects and focuses rotationally symmetrically about said axis of symmetry light

that passes through said input aperture to the at least one detector; said exit aperture being located opposite to the input aperture;

a Dove prism, having with the at least one detector an axis of symmetry about a line perpendicular to the wafer's surface and parallel to said Dove prism's base, said Dove prism being rotated about said axis of symmetry, so as to rotate light passing through said Dove prism at twice the angular velocity of said Dove prism in the opposite direction about said axis of symmetry; and

at least one filter located between said Dove prism and said at least one detector and being configured to pass to said at least one detector scattered light rays substantially other than scattered light part being scattered from at least one of said patterns.

15) The optical system of Claim **14,** further comprising a first lens assembly disposed between the at least one filter and said Dove prism, said lens assembly focusing the light beam substantially at said wafer's surface and second lens assembly disposed between said mirrored surface and said Dove prism, said second lens assembly collimating the reflected light beam.

16) The optical system of Claim **14,** further comprising first lens assembly disposed between said mirrored surface and said Dove prism, said first lens assembly collimating scattered light rays passing through said mirrored surface's exit aperture, so that light passing through said at least one filter is perpendicular to at least one filter's surface and second lens assembly disposed between said at least one filter and at least one detector, said second lens assembly focusing the light passing through said at least one filter substantially at the at least one detector.

17) An optical system for detecting defects on a wafer that includes at least one pattern; the system comprising:

a source of light to produce a beam;

optics directing the beam along a path onto the wafer, producing an illuminated spot thereon;

an array of detectors for detecting light;

an ellipsoidal mirrored surface, said mirrored surface and the array of detectors having an axis of symmetry about a line perpendicular to the wafer surface, said mirrored surface defining an input aperture positioned proximate to the wafer surface to receive scattered light therethrough from the surface; said mirrored surface further defining an exit aperture and being substantially rotationally symmetric about said axis of symmetry, so that said mirrored surface reflects and focuses rotationally symmetrically about said axis of symmetry light that passes through said input aperture to the array of detectors; said exit aperture being located opposite to said input aperture;

a Dove prism, said Dove prism and the array of detectors having an axis of symmetry about a line perpendicular to the wafer surface and parallel to said Dove prism's base, said Dove prism being rotated about said axis of symmetry, so as to rotate light passing through said Dove prism at twice the angular velocity of said Dove prism in the opposite direction about said axis of symmetry; said Dove prism further being configured to pass to said array of detectors scattered light rays substantially other than scattered light part being scattered from at least one of said patterns.

18) The optical system of Claim **17,** further comprising first lens assembly disposed between said array of detectors and said Dove prism, said lens assembly focusing the light beam substantially at said wafer's surface and second lens assembly disposed between said mirrored surface and said Dove prism, said second lens assembly collimating the reflected light beam.

19) The optical system of Claim **17**, further comprising lens assembly disposed between said mirrored surface and said Dove prism, said first lens assembly

collimating scattered light rays passing through said said mirrored surface's exit aperture, so that light impinging on said array of detectors is perpendicular to said array of detectors.

20) An optical system for detecting defects on a wafer that includes at least one pattern; the system comprising:

a source of light to produce a beam;

means for directing the beam along a path onto the wafer, producing an illuminated spot thereon;

at least one means for detecting light;

an ellipsoidal mirrored surface, said mirrored surface and the at least one detecting means having an axis of symmetry about a line perpendicular to the wafer surface, said mirrored surface defining an input aperture positioned proximate to the wafer surface to receive scattered light therethrough from the surface; said mirrored surface further defining an exit aperture and being substantially rotationally symmetric about said axis of symmetry, so that the mirrored surface reflects and focuses rotationally symmetrically about said axis of symmetry light that passes through the input aperture to the at least one detecting means; said exit aperture being located opposite to the input aperture; and

at least one filter located between said exit aperture and said at least one detecting means and being configured to pass to said at least one detecting means scattered light rays substantially other than scattered light part being scattered from at least one of said patterns.

21) An optical system for detecting defects on a wafer that includes at least one pattern; the system comprising:

a source of light to produce a beam;

means for directing the beam along a path onto the wafer surface, producing an illuminated spot thereon;

an array of detecting means for detecting light;

an ellipsoidal mirrored surface, said mirrored surface and the array of detecting means having an axis of symmetry about a line perpendicular to the wafer, said mirrored surface defining an input aperture positioned proximate to the test surface to receive scattered light therethrough from the surface; said mirrored surface further defining an exit aperture and being substantially rotationally symmetric about said axis of symmetry, so that the mirrored surface reflects and focuses rotationally symmetrically about said axis of symmetry light that passes through the input aperture to the array of detecting means; said exit aperture being located between said array of detecting means and said input aperture;

said array of detecting means are adapted to detect scattered light substantially other than scattered light part being scattered from at least one of said patterns.

22) An optical system for detecting defects on a wafer, comprising:

a device for producing a beam and directing the beam onto the wafer surface, so as to produce an illuminated spot thereon;

at least one detector detecting light;

a mirrored assembly having together with the at least one detector an axis of symmetry about a line perpendicular to the wafer surface, said assembly is configured to receive scattered light from the surface; said assembly further configured to reflect and focus rotationally symmetrically about said axis of symmetry the scattered light to the at least one detector; and

a device associated with said at least one detector for facilitating detection of a scattered light substantially other than scattered light part being scattered from at least one of said patterns.

23) The optical system of Claim **22**, wherein said wafer is patterned.

24) An optical system for detecting defects on a wafer, comprising:

a device for producing a beam and directing the beam onto the wafer surface, so as to produce an illuminated spot thereon;

at least one detector detecting light;

a mirrored assembly configured to receive scattered light from the surface; said assembly further configured to reflect the scattered light to the at least one detector; and

a device associated with said at least one detector for facilitating detection of a scattered light substantially other than scattered light part being scattered from at least one of said patterns.

25) The optical system of Claim **24**, wherein said wafer is patterned.

26) An optical method for detecting defects on a wafer that includes at least one pattern; the method comprising:

providing a beam of light;

directing the beam along a path onto the wafer, producing an illuminated spot thereon;

positioning an ellipsoidal mirrored surface and at least one detector so that they have an axis of symmetry about a line perpendicular to the wafer surface, said mirrored surface defining an input aperture positioned proximate to the wafer surface to receive scattered light therethrough from the surface; said mirrored surface further defining an exit aperture and being substantially rotationally symmetric about said axis of symmetry, so that the mirrored surface reflects and focuses rotationally symmetrically about said axis of symmetry light that passes through the input aperture to the at least one detector; said exit aperture being located opposite to the input aperture; and

locating at least one filter between said exit aperture and said at least one detector, configuring the at least one filter to pass to said at least one detector scattered light rays substantially other than scattered light part being scattered from at least one of said patterns.

27) An optical method for detecting defects on a wafer that includes at least one pattern; the method comprising:

providing a beam of light;

directing the beam along a path onto the wafer surface, producing an illuminated spot thereon;

positioning an ellipsoidal mirrored surface and an array of detectors so that they have an axis of symmetry about a line perpendicular to the wafer, said mirrored surface defining an input aperture positioned proximate to the test surface to receive scattered light therethrough from the surface; said mirrored surface further defining an exit aperture and being substantially rotationally symmetric about said axis of symmetry, so that the mirrored surface reflects and focuses rotationally symmetrically about said axis of symmetry light that passes through the input aperture to the array of detectors; said exit aperture being located between said array of detectors and said input aperture;

adapting said array of detectors to detect scattered light substantially other than scattered light part being scattered from at least one of said patterns.

28) An optical method for detecting defects on a wafer that includes at least one pattern; the method comprising:

providing a beam of light;

directing the beam along a path onto the wafer, producing an illuminated spot thereon;

positioning an ellipsoidal mirrored surface and at least one detector so that they have an axis of symmetry about a line perpendicular to the wafer surface, said mirrored surface defining an input aperture positioned proximate to the

wafer surface to receive scattered light therethrough from the surface; said mirrored surface further defining an exit aperture and being substantially rotationally symmetric about said axis of symmetry, so that the mirrored surface reflects and focuses rotationally symmetrically about said axis of symmetry light that passes through said input aperture to the at least one detector; said exit aperture being located opposite to the input aperture;

positioning a Dove prism, so as to have with the at least one detector an axis of symmetry about a line perpendicular to the wafer's surface and parallel to said Dove prism's base; said Dove prism is rotated about said axis of symmetry, so as to rotate light passing through said Dove prism at twice the angular velocity of said Dove prism in the opposite direction about said axis of symmetry; and

locating at least one filter between said Dove prism and said at least one detector and configuring the filter to pass to said at least one detector scattered light rays substantially other than scattered light part being scattered from at least one of said patterns.

29) An optical method for detecting defects on a wafer that includes at least one pattern; the method comprising:

providing a beam of light;

directing the beam along a path onto the wafer, producing an illuminated spot thereon;

positioning an ellipsoidal mirrored surface and an array of detectors so that they have an axis of symmetry about a line perpendicular to the wafer surface, said mirrored surface defining an input aperture positioned proximate to the wafer surface to receive scattered light therethrough from the surface; said mirrored surface further defining an exit aperture and being substantially rotationally symmetric about said axis of symmetry, so that said mirrored surface reflects and focuses rotationally symmetrically about said axis of symmetry light that passes through said input aperture to the array of detectors; said exit aperture being located opposite to said input aperture;

positioning a Dove prism so as to have with the array of detectors an axis of symmetry about a line perpendicular to the wafer surface and parallel to said Dove prism's base; said Dove prism is rotated about said axis of symmetry, so as to rotate light passing through said Dove prism at twice the angular velocity of said Dove prism in the opposite direction about said axis of symmetry; said Dove prism is further being configured to pass to said array of detectors scattered light rays substantially other than scattered light part being scattered from at least one of said patterns.

30) An optical method for detecting defects on a wafer, comprising:

providing a device for producing a beam and directing the beam onto the wafer surface so as to produce illuminated spot thereon;

positioning a mirrored assembly and at least one detector so that they have an axis of symmetry about a line perpendicular to the wafer surface; configuring said assembly to receive scattered light from the surface and further configuring said assembly to reflect and focus rotationally symmetrically about said axis of symmetry the scattered light to the at least one detector; and

positioning a device associated with said at least one detector for facilitating detection of a scattered light substantially other than scattered light part being scattered from at least one of said patterns.

31) An optical method for detecting defects on a wafer, comprising:

providing a device for producing a beam and directing the beam onto the wafer surface so as to produce an illuminated spot thereon;

positioning a mirrored assembly configured to receive scattered light from the surface and further configuring said assembly to reflect the scattered light to the at least one detector; and

positioning a device associated with said at least one detector for facilitating detection of a scattered light substantially other than scattered light part being scattered from at least one of said patterns.

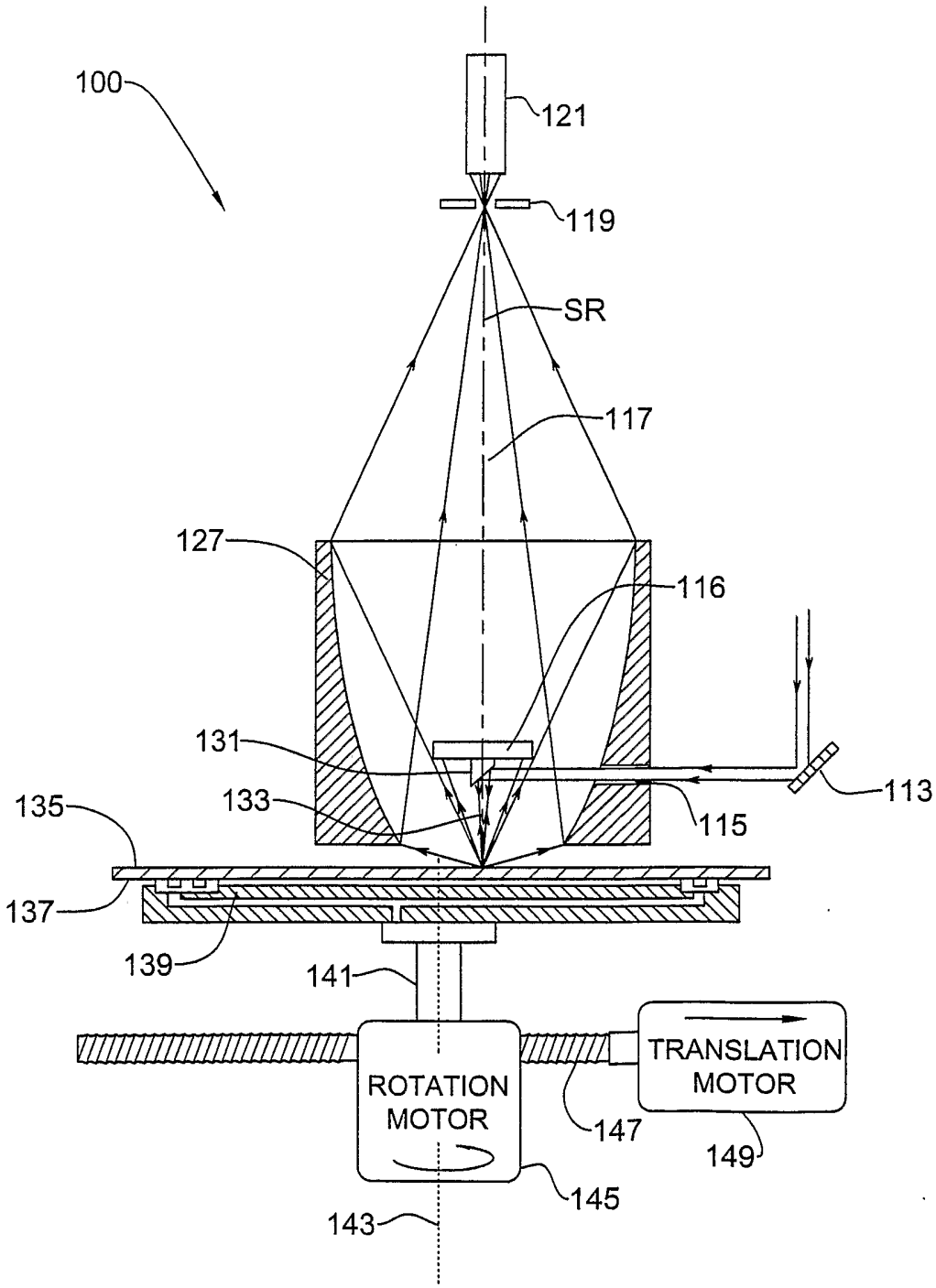

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FIG. 1A

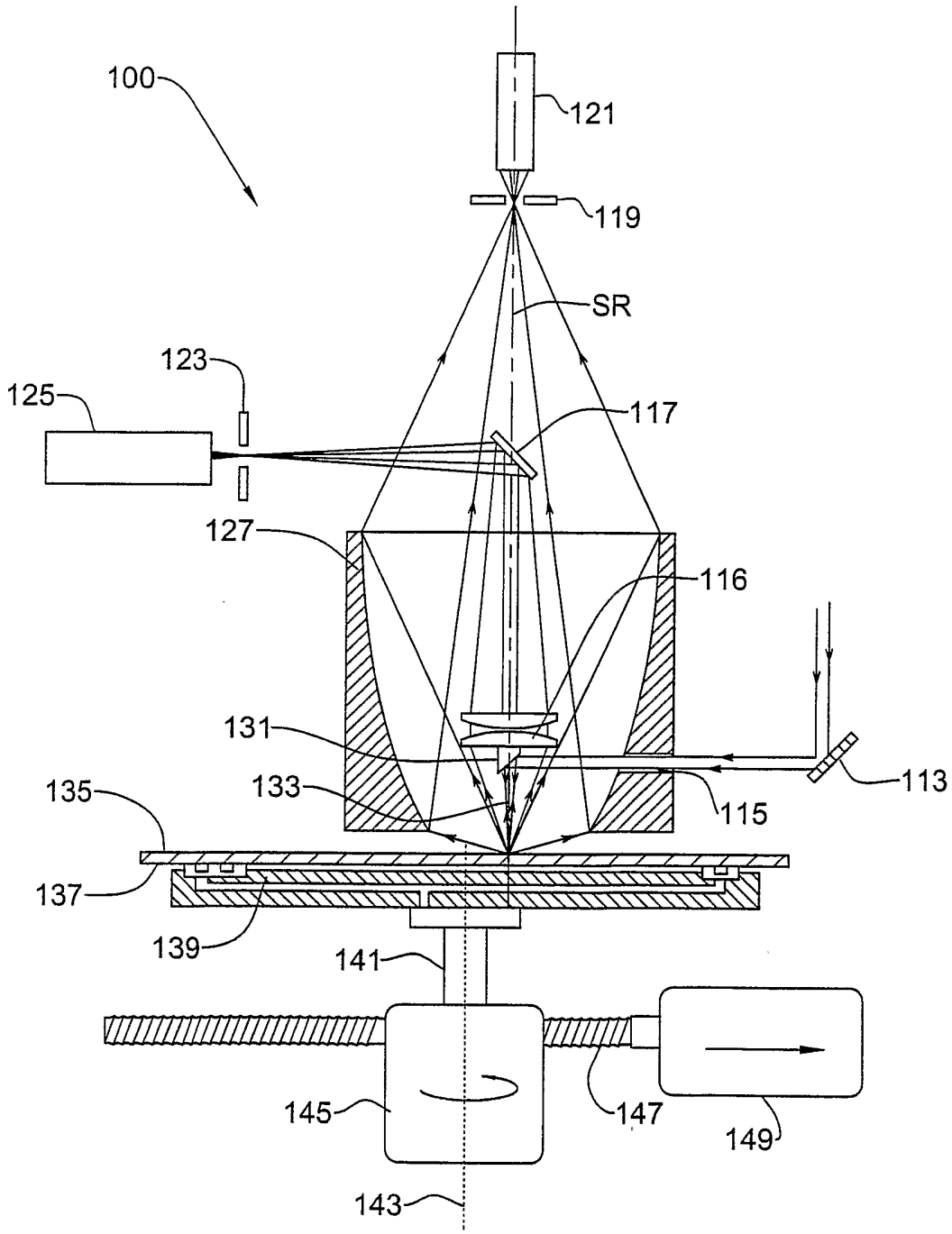

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FIG. 1B

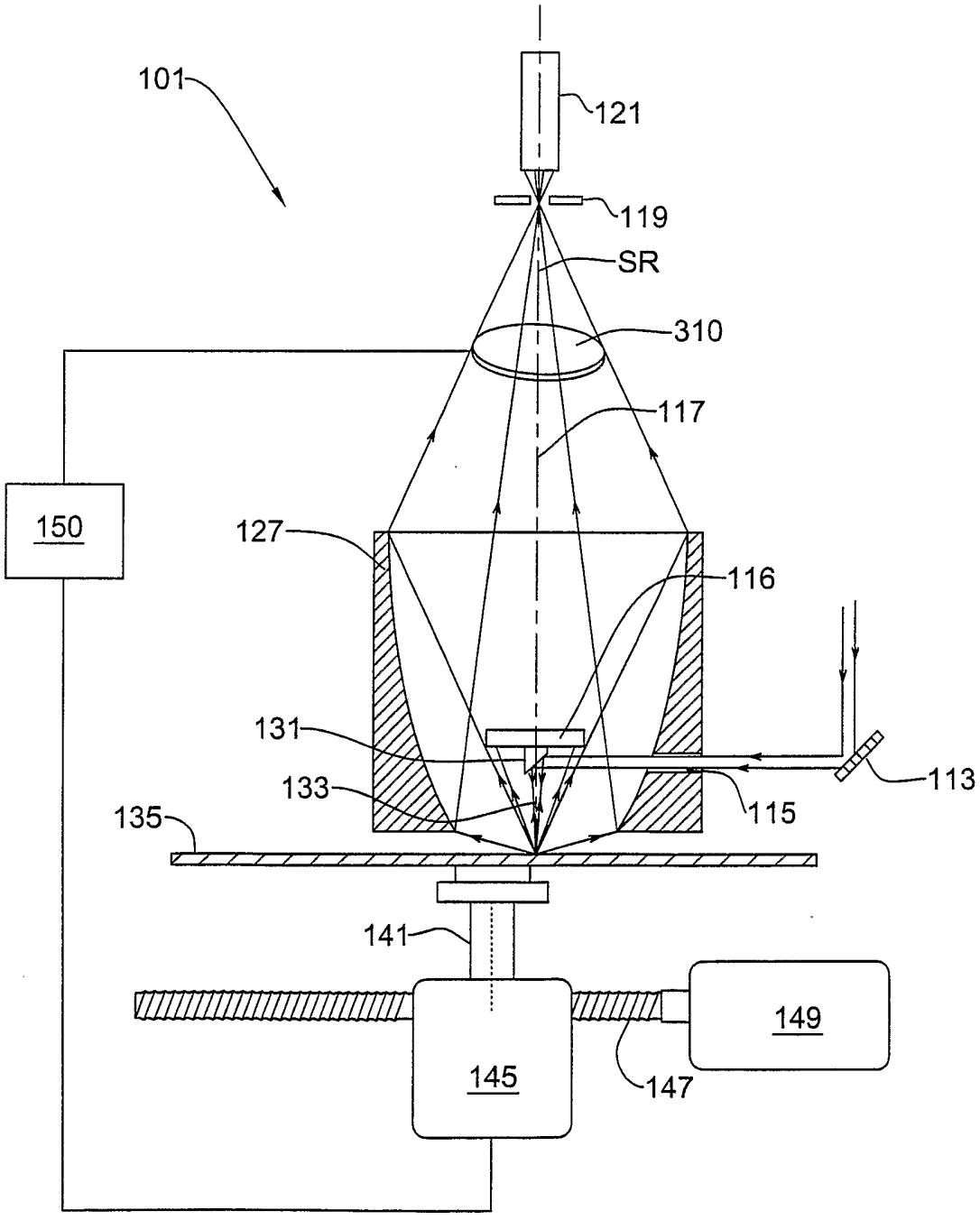

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FIG. 2A

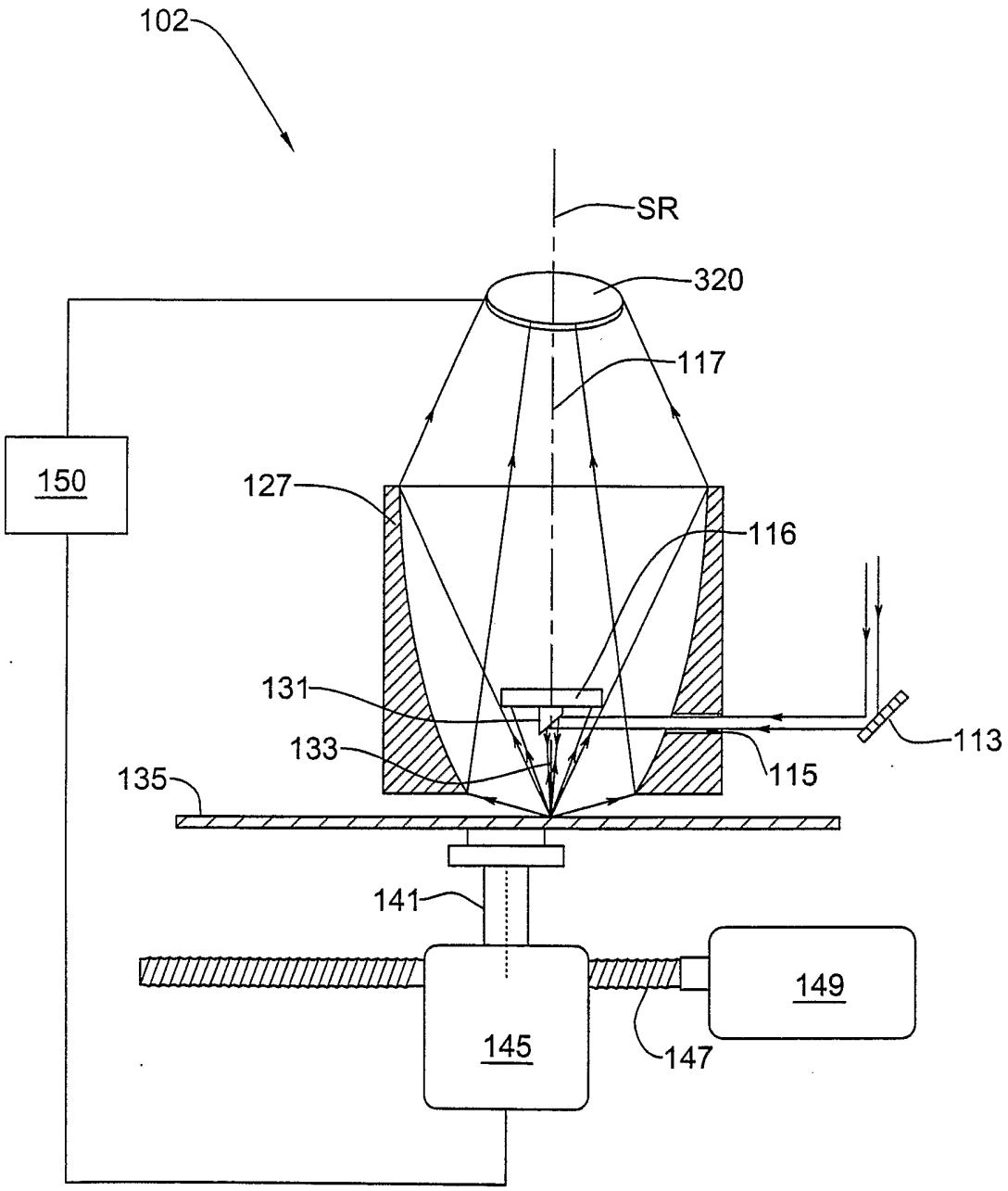


FIG. 2B

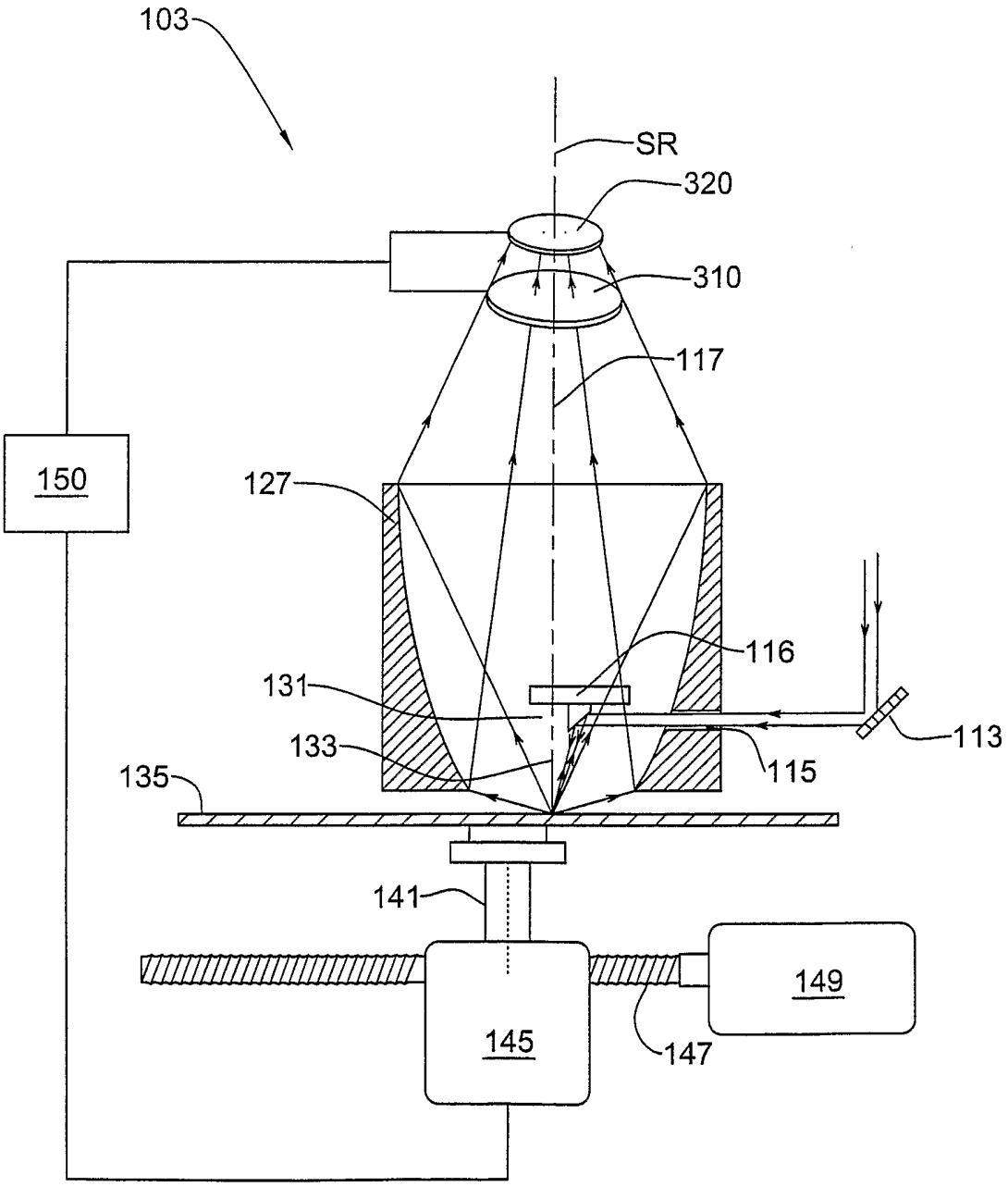

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FIG. 2C

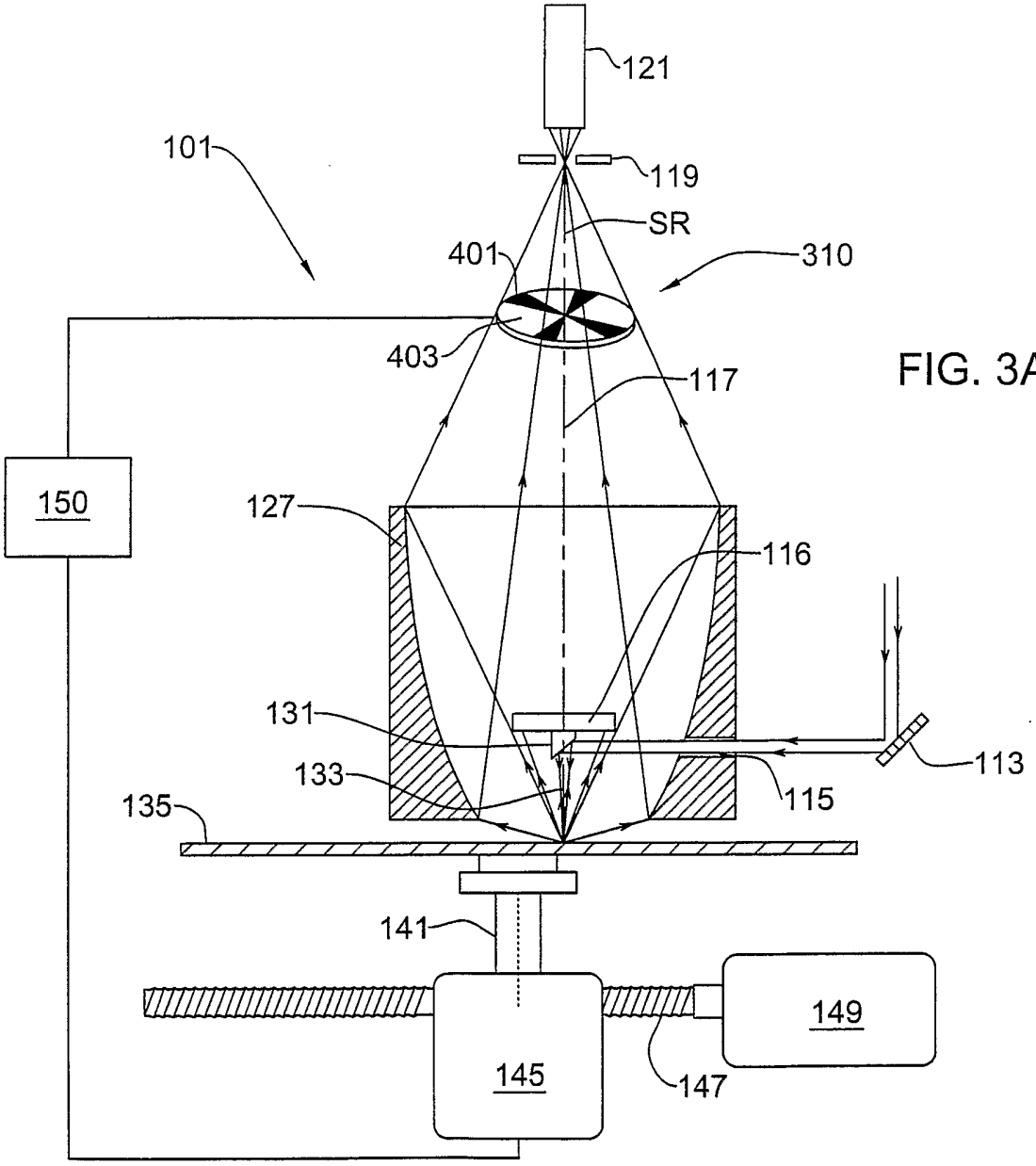


FIG. 3A

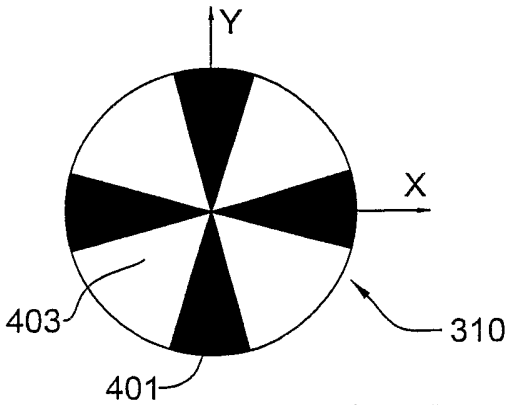


FIG. 3B

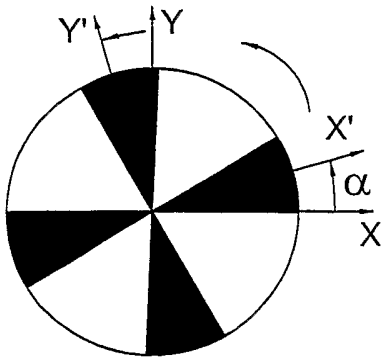


FIG. 3C

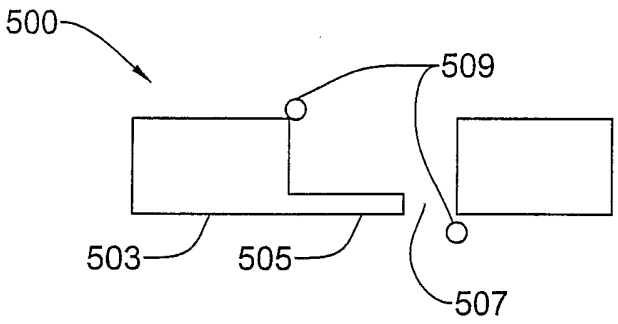


FIG. 4A

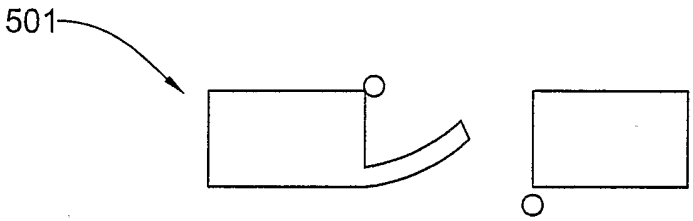


FIG. 4B

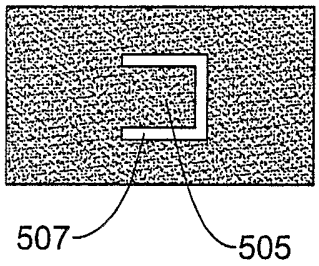


FIG. 4C

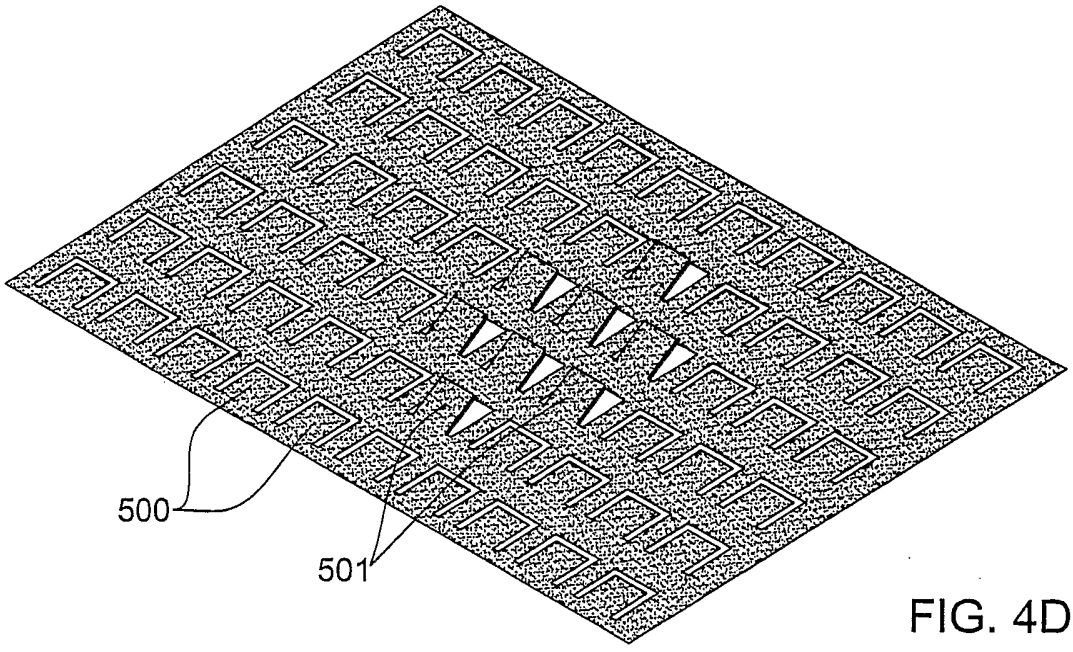


FIG. 4D

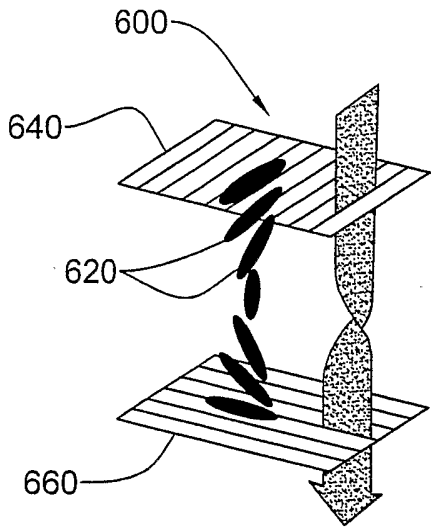


FIG. 5A

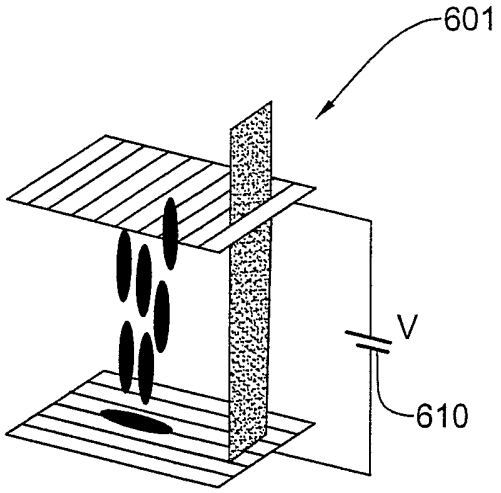


FIG. 5B

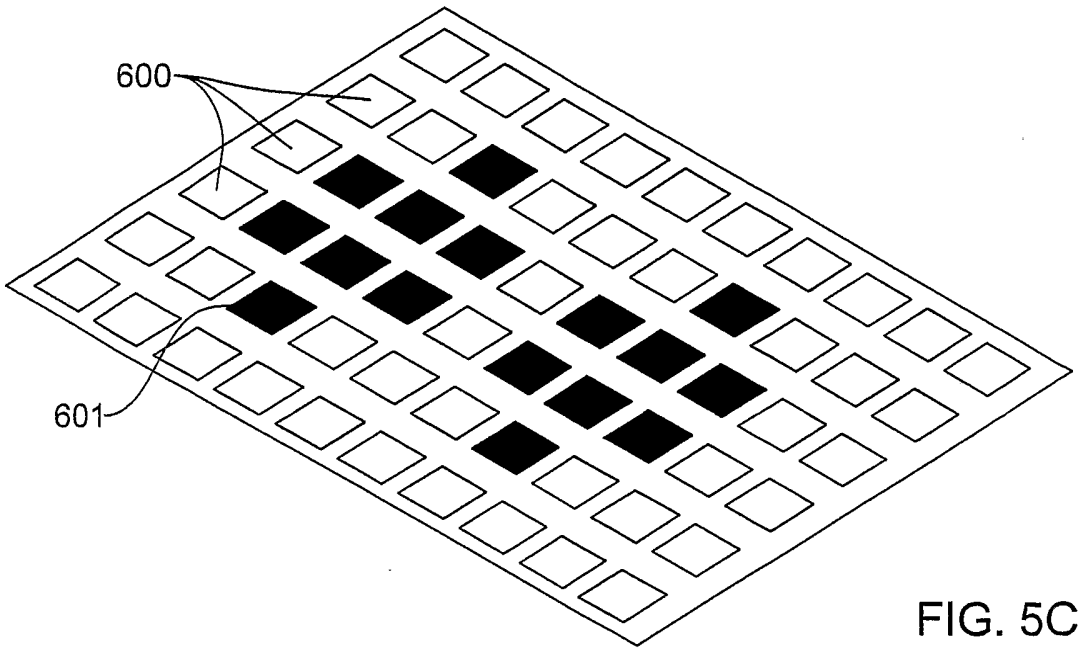


FIG. 5C

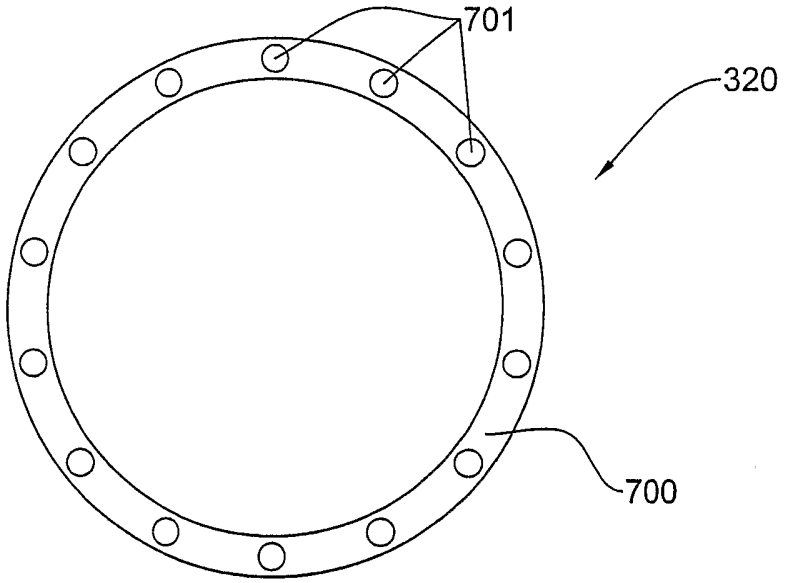


FIG. 6A

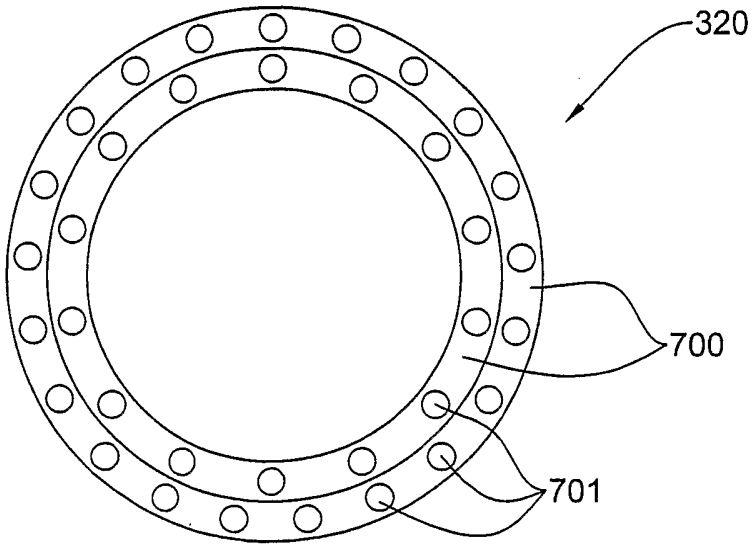


FIG. 6B

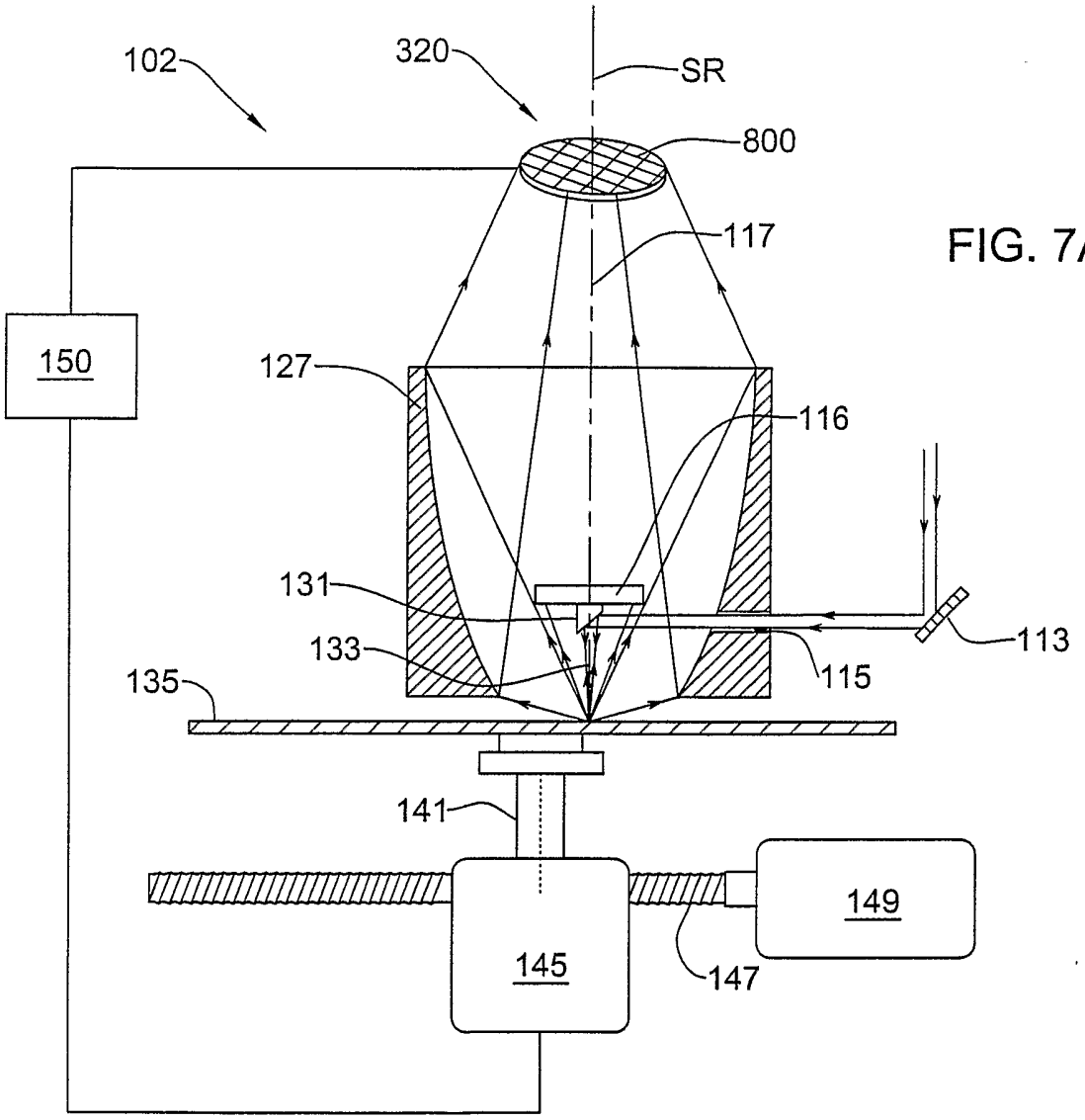


FIG. 7A

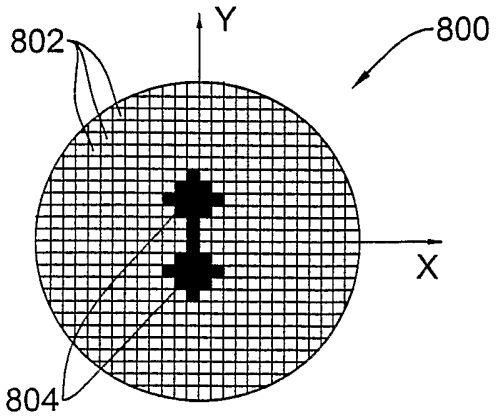


FIG. 7B

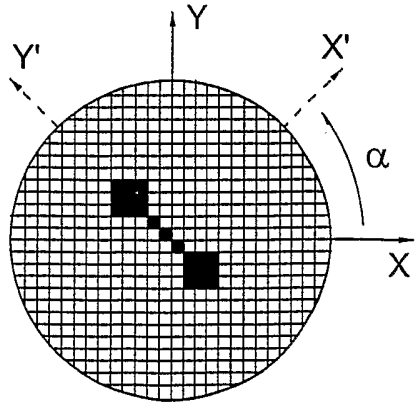


FIG. 7C

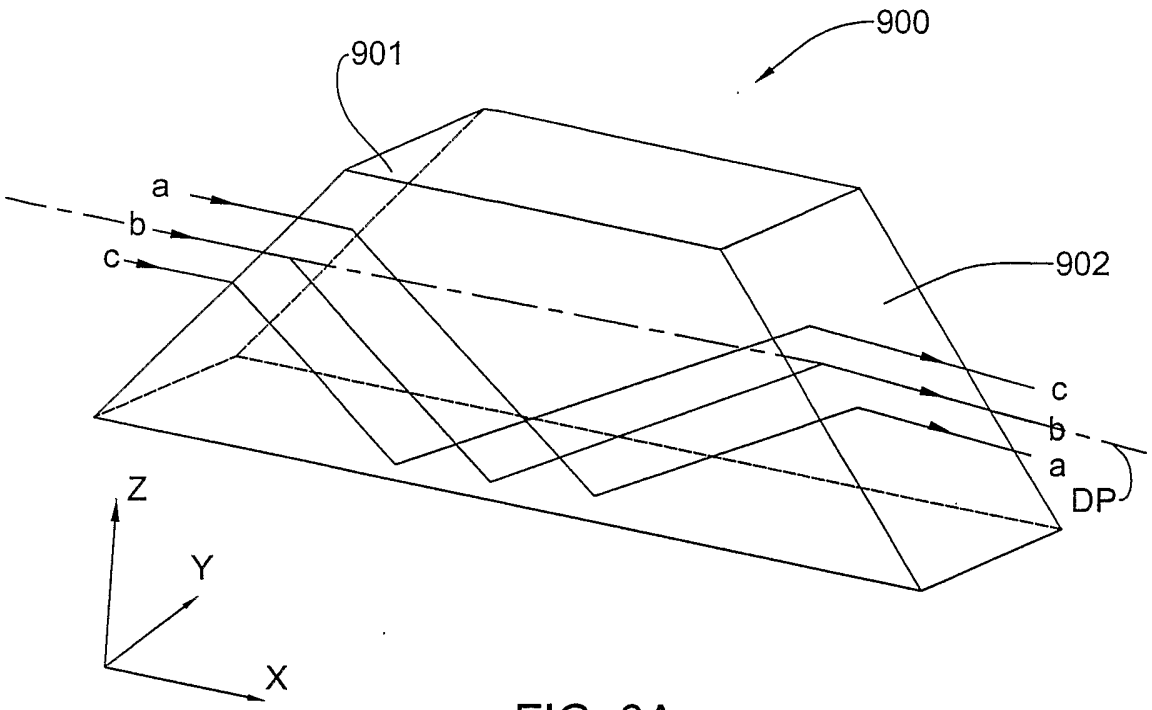

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FIG. 8A

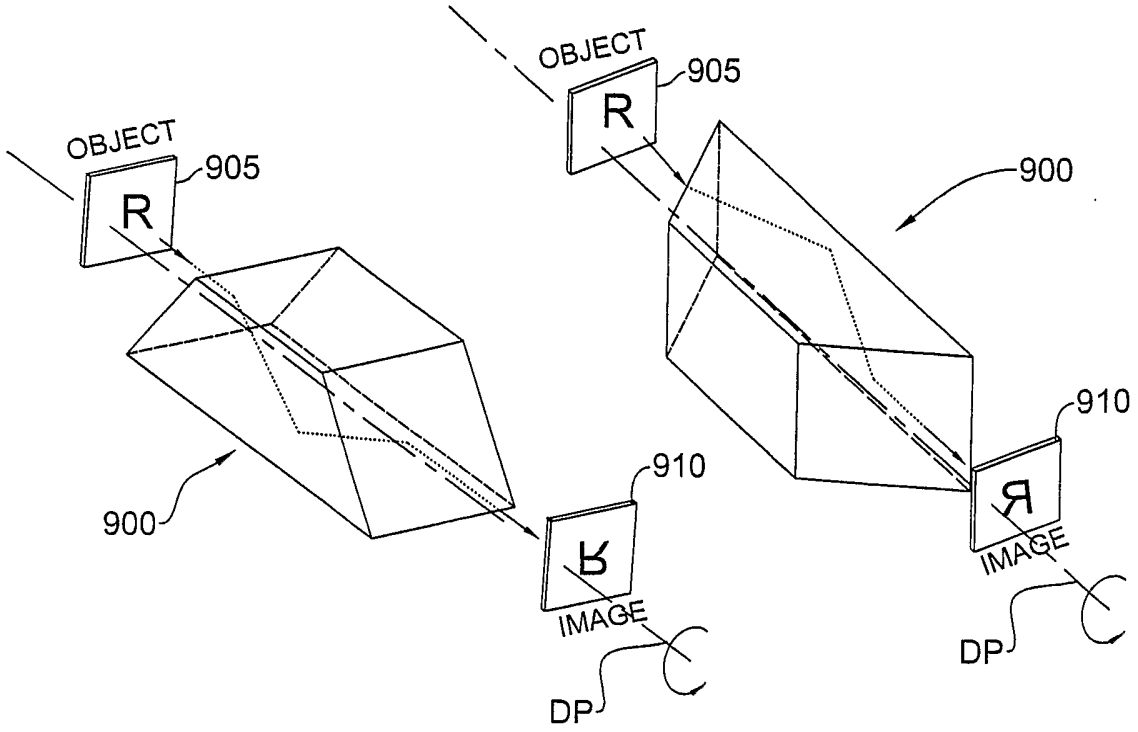

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FIG. 8B

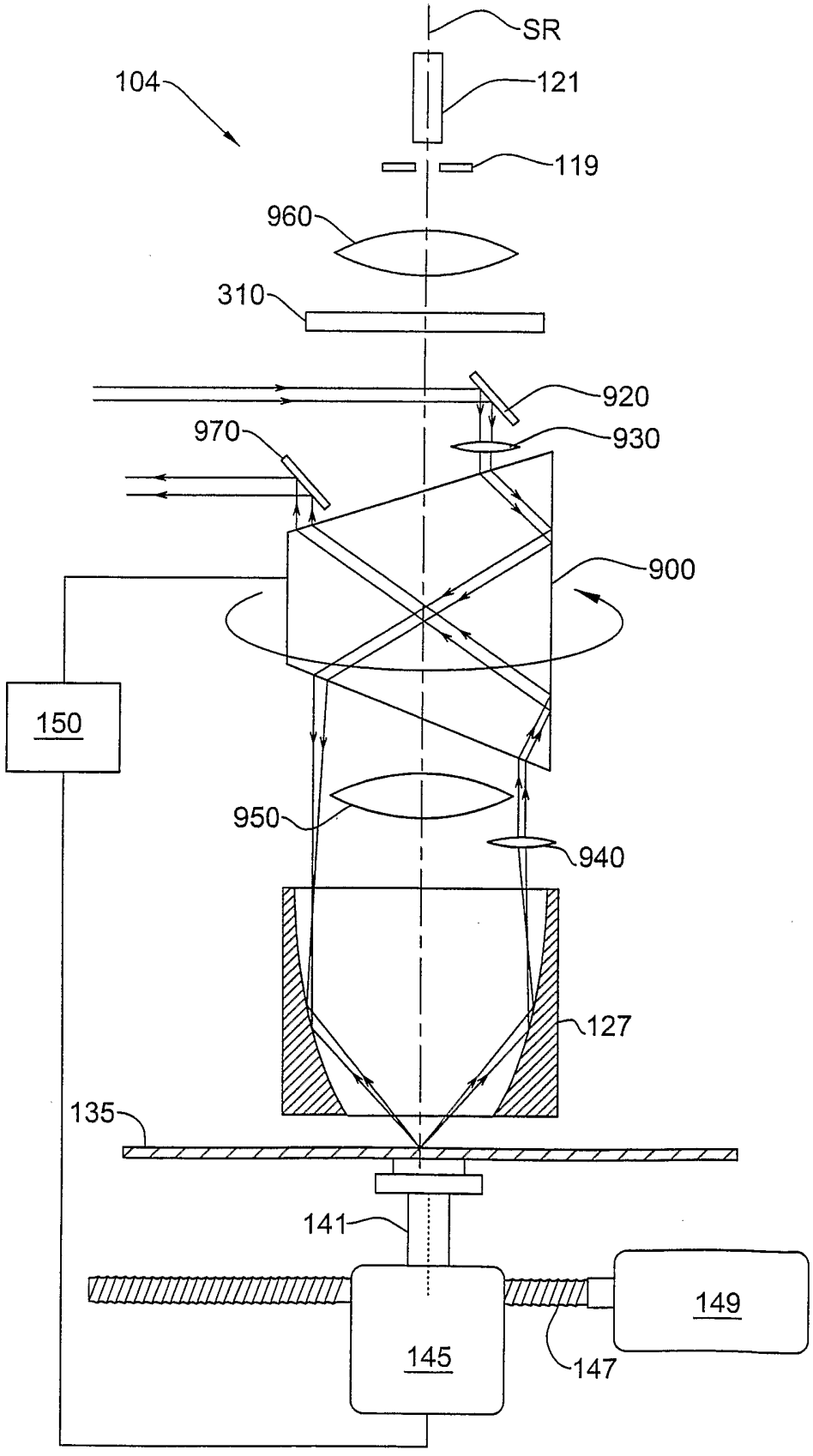

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FIG. 8C

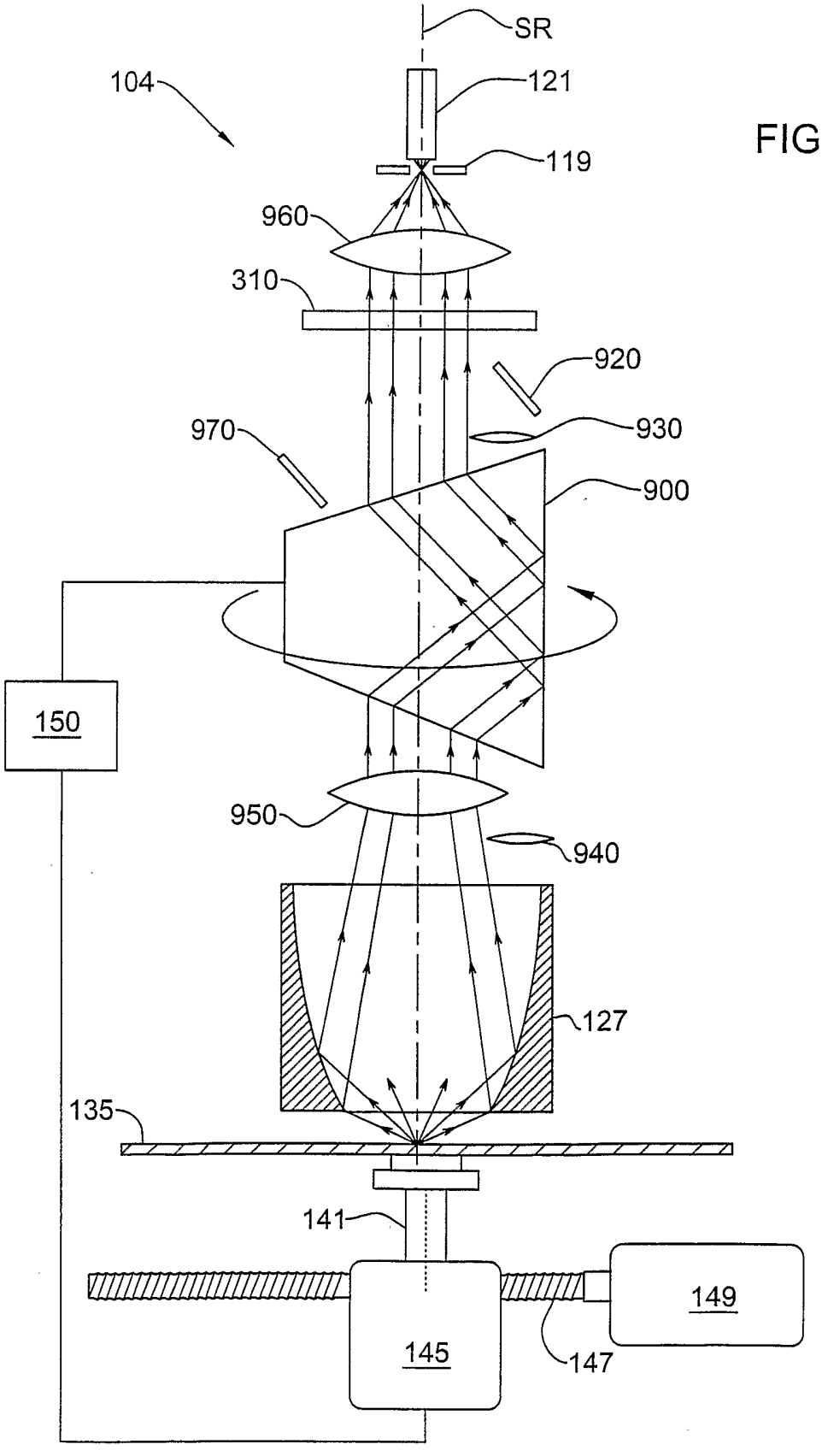

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FIG. 8D

INTERNATIONAL SEARCH REPORT

Int. Application No
PCT/US 03/22786

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01N21/95 G01N21/956

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01N

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X Y	WO 01 98755 A (APPLIED MATERIALS INC) 27 December 2001 (2001-12-27) page 3, line 23 - line 26 page 6, line 13 -page 8, line 13 page 14, line 24 - line 25 page 20, line 27 -page 21, line 13	22-25, 30,31 1-6,20, 26

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 November 2003	10/12/2003

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Bockstahl, F

INTERNATIONAL SEARCH REPORT

Inte ıal Application No
PCT/US 03/22786

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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Y	WO 99 56113 A (ROSENGAUS ELIEZER ;KLA TENCOR CORP (US); LANGE STEVEN R (US)) 4 November 1999 (1999-11-04) page 1, line 25 -page 2, line 5 page 19, line 13 - line 24	10,11
X A	US 4 598 997 A (AUDERSET HEINRICH ET AL) 8 July 1986 (1986-07-08) abstract; figures 3,4 column 4, line 19 -column 5, line 45	22-25, 30,31 1-21, 26-29
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INTERNATIONAL SEARCH REPORT

Inte ıal Application No
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