PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : G02B 21/24

A1

(11) International Publication Number: WO 91/18313

(43) International Publication Date: 28 November 1991 (28.11.91)

(21) International Application Number: PCT/US91/03536

(22) International Filing Date: 20 May 1991 (20.05.91)

(30) Priority data:
526,049 21 May 1990 (21.05.90) US

(71) Applicant: INTERACTIVE VIDEO SYSTEMS, INC. [US/US]; 45 Winthrop Street, Concord, MA 01742 (US).

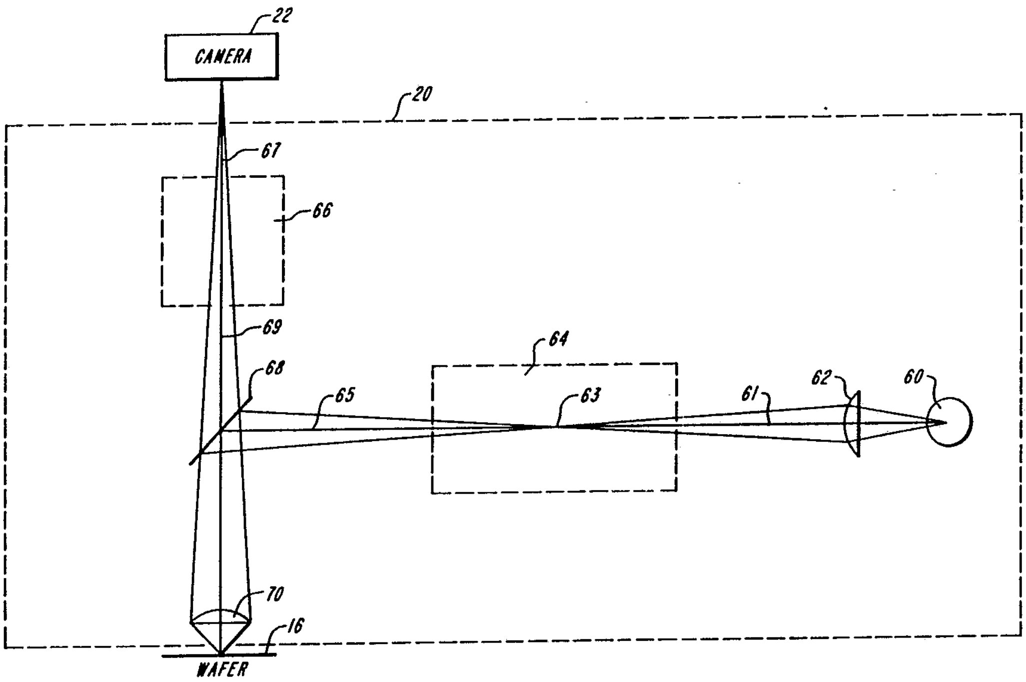
(72) Inventors: SAPORETTI, Eutimio, A. ; 73 Hunt Road, Chelmsford, MA 01824 (US). INTO, Stephen, W. ; 6 Garden Road, Billerica, MA 01821 (US).

(74) Agent: KUDIRKA, Paul, E.; Wolf, Greenfield & Sacks, 600 Atlantic Avenue, Boston, MA 02210 (US).

(81) Designated States: AT (European patent), BE (European patent), CH (European patent), DE (European patent), DK (European patent), ES (European patent), FR (European patent), GB (European patent), GR (European patent), IT (European patent), JP, KR, LU (European patent), NL (European patent), SE (European patent).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: PROJECTED IMAGE FOCUS SYSTEM AND METHOD OF USE



(57) Abstract

In a semiconductor process-control measurement system which forms an image of a semiconductor wafer surface and performs measurements by image processing techniques, a predetermined focussing pattern is optically projected onto the wafer surface by means of a microscope system used for obtaining the wafer image. Optical system focussing is then accomplished by adjusting the optical system until the projected pattern (rather than a physical edge of a feature on the wafer itself) is in focus.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	**ES**	Spain	**MG**	Madagascar
AU	Australia	**FI**	Finland	**ML**	Mali
BB	Barbados	**FR**	France	**MN**	Mongolia
BE	Belgium	**GA**	Gabon	**MR**	Mauritania
BF	Burkina Faso	**GB**	United Kingdom	**MW**	Malawi
BG	Bulgaria	**GN**	Guinea	**NL**	Netherlands
BJ	Benin	**GR**	Greece	**NO**	Norway
BR	Brazil	**HU**	Hungary	**PL**	Poland
CA	Canada	**IT**	Italy	**RO**	Romania
CF	Central African Republic	**JP**	Japan	**SD**	Sudan
CG	Congo	**KP**	Democratic People's Republic of Korea	**SE**	Sweden
CH	Switzerland			**SN**	Senegal
CI	Côte d'Ivoire	**KR**	Republic of Korea	**SU**	Soviet Union
CM	Cameroon	**LI**	Liechtenstein	**TD**	Chad
CS	Czechoslovakia	**LK**	Sri Lanka	**TG**	Togo
DE	Germany	**LU**	Luxembourg	**US**	United States of America
DK	Denmark	**MC**	Monaco		

PROJECTED IMAGE FOCUS SYSTEM AND METHOD OF USE

Field of the Invention

This invention relates to methods and apparatus used in the manufacture of semiconductor wafers and, more particularly, to methods and apparatus for focussing an optical microscope on a wafer surface for metrology purposes.

Background of the Invention

During the manufacture of semiconductor devices, it is desirable to make selected measurements at several steps in the manufacturing process to determine whether the devices are within design specification ranges. In this manner, process problems can be quickly discovered and timely corrective action taken to ensure maximum yields. Alternatively, measurements may be taken to establish initial process limits and research techniques. Such measurements may include critical dimension, overlay registration verification and contact hole measurements.

Critical dimension measurements are performed to ensure that feature widths and thicknesses are within the design specifications. Present semiconductor designs often require tight width and thickness tolerances because incorrect feature thickness or width may alter signal characteristics and prevent the device from functioning properly.

Overlay registration verification ensures that the different layers of a multi-layered device are placed correctly over one another. Malfunction of the device may occur when the layers are "misregistered" producing poor layer-to-layer contacts.

Contact hole measurements ensure that contact hole dimensions are within design specifications and that the holes penetrate completely from one layer to the next. The dimensions of the contact holes also affect electric current propagation through the device and, therefore, are often crucial for proper operation.

As semiconductor devices become smaller and reach higher speeds, the number of dies per wafer is increased and die size is decreased. As a consequence, feature thicknesses and linewidths are shrinking and the equipment which performs process-control measurements must perform to higher standards of accuracy with lower allowable error tolerances.

In the past, it was common practice to manually make process-control measurements - experienced operators examined the semiconductor wafers under a microscope. This manual technique was relatively slow, was prone to to human error and often subjected the semiconductor wafers to contamination. In order to obtain higher process yields, it was found necessary to quickly perform process-control measurements at several junctures during the fabrication process and to automate the measurement process in order to minimize contaminants introduced by humans.

Consequently, automated systems for measuring process-control parameters have been developed. In one highly successful measurement system, process control measurements are made electronically by means of a video camera. The camera records an image of a wafer feature through a microscope and the recorded image is then processed electronically to obtain the required measurements.

While automated systems overcome many of the limitations of the manual technique, certain errors are still introduced into the measured values by both the optical and the electronic portions of the system. For example, one known source of errors in the aforementioned automated system occurs due to focussing variations in the optical microscope system which conveys the wafer image to the video camera. The techniques which are used to precisely locate the positions of the feature edges require that the recorded image of those edges be sharply defined in order to generate accurate measurements. If the edges are blurred by an inaccurate focus of the optical system before their image is recorded by the video camera, then the accuracy of the measurement is reduced.

Consequently, automated focussing systems have been developed which adjust the optical microscope focus by moving stage 18 until the optical system is properly focussed on the object feature. Such prior art focussing systems include video, laser, scanning and capacitive sensor focussing systems. Video focussing systems operate by capturing an image of a feature edge and calculating edge contrast by known mathematical techniques. Stage 18 is then moved and a new image is captured. The edge contrast is then recalculated. This process is repeated until several contrast calculations have been made. Based on the calculations, a maximum contrast position is then calculated at which edge contrast is maximized. Stage 18 is then moved to the maximum contrast position.

Laser focussing arrangements project one or more laser beams through one side of the optical system. The beams are reflected from the wafer surface and return through the other side of the optical system. If a single laser beam is used, optical sensors detect the position of the reflected, returning beam and operate an electronic servo system to move stage 18 until the returning beam is located in a known position.

Scanning focussing systems project an illuminated "spot" onto the wafer surface. As the spot is scanned in a line across the wafer surface, the spot size is measured by sensors and a servo system is used to adjust stage 18 until the measured spot size is within predetermined size limits.

Capacitive sensor focussing systems use a capacitive proximity sensor located on the microscope (alternatively, the microscope objective may be modified to act as a proximity sensor). The proximity sensor senses the distance between the microscope objective lens and the wafer surface. A servo system is used to adjust stage 18 until the sensed distance equals a predetermined distance which is known to be the focal distance of the microscope objective lens.

The aforementioned automatic focussing arrangements operate satisfactorily for relatively coarse adjustments, but, as circuit size has diminished, the focussing requirements have become more and more stringent so that prior art focussing systems experience problems focussing the optical system to attain necessary measurement goals.

For example, a typical circuit feature on the wafer may have slanted or rough edges due to the process which is used to form the feature. Therefore, for the reasons discussed above, it is often desirable to accurately measure a circuit feature width at a predetermined plane above the wafer surface. Consequently, when prior art focussing systems are used to focus the optical system, those portions of the feature edge which are adjacent to the desired position, but lie above or below the desired plane (and, consequently, are out-of-focus) become involved in the focussing process and interfere with the attainment of an accurate focus. For example, if the prior art video focussing systems are used, the out-of-focus portions of the feature edge which are above and below the desired plane are present in the captured image and therefore enter into the contrast calculations as unwanted information or "noise". The "signal-to-noise" ratio of the calculations is thereby reduced.

The prior art laser and scanning techniques are dependent on spot size to produce an accurate focus and, typically, are not accurate enough for high resolution work. In addition it is difficult to place the laser spot at a particular position within the microscope image and the focussing equipment is expensive and complicated.

Capacitive sensor arrangements also suffer from similar problems and are generally not accurate enough for high resolution work. In addition, if the wafer is not precisely positioned with respect to the sensor, a location which is above or below the desired plane may be used.

Accordingly, it is a general object of the present invention to provide improved focussing apparatus for optical systems.

It is another object of the present invention to provide focussing apparatus which improves the ability of an optical system to focus on a feature within the field of view.

It is a further object of the present invention to provide apparatus for focussing the optical apparatus in a process-control measurement system.

It is another object of the present invention to provide apparatus for focussing a process-control measurement optical system on a feature which apparatus does not rely on the feature itself.

It is yet another object of the present invention to provide apparatus for focussing the process-control measurement optical system which is easy to use.

It is yet another object of the present invention to provide apparatus for focussing the process-control measurement optical system which operates rapidly.

It is still another object of the present invention to provide apparatus for focussing the optical system in a process-control measurement apparatus at known positions above and below the wafer surface.

Summary of the Invention

According to the present invention, the foregoing problems are overcome and the foregoing objects and advantages are achieved in one illustrative embodiment in which a predetermined focussing pattern is optically projected onto the wafer surface by means of the microscope system used for obtaining the wafer image (the term "wafer surface" is used herein as a short description of the plane to which the focussing pattern is projected. As used herein, projecting a focussing pattern on the wafer surface means that the focussing pattern is projected onto a plane which may be at, above or below the actual wafer surface). Focussing is then accomplished by capturing images of the projected pattern and adjusting the optical system until the calculated contrast of an edge of the projected pattern (rather than a physical feature edge itself) is maximized.

More particularly, when an object is placed at a position in the microscope optical system where its projected image is focussed on the wafer surface, the projected image can be viewed through the microscope.

If the wafer is moved so that the object is no longer at this position, the projected image appears to become "out-of-focus". Consequently, when the image is in focus, the wafer surface is also in focus.

The focussing pattern is obtained by placing at least one image source in the field plane of the microscope system. The image source can be any convenient focussing pattern including a knife edge, or one or more lines or spots. The image source is illuminated such that its image is projected onto the wafer surface. After the optical system has been properly focussed, the projected image may be removed during actual measurements.

It is a further improvement of the invention to utilize a three-dimensional image source so that multiple focussing images are projected onto an object surface simultaneously. In this manner, as will hereinafter be explained in detail, information regarding the optimum focus can be obtained more quickly. In addition, the optical system can be focussed at pre-selected positions without relying on precise accuracy of the mechanism which moves the object.

Brief Description of Drawings

For a better understanding of the present invention together with other and further objects, advantages and capabilities thereof, reference is made to the accompanying drawings which are incorporated herein by reference and in which:

Fig. 1 is an illustration of a process-control measurement system suitable for incorporation of the present invention;

Fig. 2 is a simplified block diagram of the process-control measurement system shown in Fig. 1;

Figs. 3A and 3B are top and partial cross-sectional views, respectively, of a typical critical dimension measurement pattern which is to be measured by the invention;

Fig. 3C illustrates an enlarged view of the cross-sectional patterns shown in Fig. 3B illustratively showing sloped feature edges;

Fig. 4 is a simplified schematic diagram of the optical system of the microscope 20 and camera 22 suitable for a measurement system such as that shown in Figs. 1 and 2;

Fig. 5A shows the placement of a self-illuminated image source into the illumination portion of the optical path shown in Fig. 4 to project a focussing pattern onto the surface of wafer 16.

Fig. 5B shows the insertion of a passively illuminated image source into the illumination portion of the optical path shown in Fig. 4 to project a focussing pattern onto the surface of wafer 16.

Fig. 6 shows an alternative placement of a self-illuminated image source in the optical path shown in Fig. 4 to to project a focussing pattern onto the surface of wafer 16.

Figs. 7A-7D show a few illustrative focussing patterns which can be projected onto the surface of wafer 16 in accordance with the invention.

Figs. 8A and 8B show front and top views, respectively, of an illustrative three-dimensional image source.

Fig. 9 illustratively shows an image generated with the image source shown in Figs. 8A and 8B as viewed through an optical system when the object is "in focus".

Detailed Description of the Invention

An automated system for making process-control measurements is illustrated in Figs. 1 and 2. An automated system suitable for use with the invention is a Model ACV4 metrology system manufactured by Interactive Video Systems, Inc. located at 45 Winthrop Street, Concord, MA 01742. The major elements of the system, including a wafer handler, an optical system and a computer system, are mounted in a cabinet 10.

The wafer handling system, in turn, includes a cassette wafer holder 12 which contains wafers to be measured, a pre-aligner 14, a wafer transport pick mechanism (not shown) for moving the wafers and a measurement stage 18 which holds the wafers during the actual measurement operation. During operation, the wafer transport pick mechanism (not shown) removes a wafer 16 from cassette 12 and places it on pre-aligner 14. Pre-aligner 14 then rotates wafer 16 to a predetermined orientation illustratively by sensing a flat spot or notched edge on wafer 16 after which the wafer transport pick mechanism transfers wafer 16 from pre-aligner 14 to measurement stage 18 and positions wafer 16 in a horizontal orientation. Stage 18 is movable in three dimensions for precisely positioning wafer 16 relative to the optical system for performing the actual measurement.

The optical system includes microscope 20 and video camera 22 positioned above the measurement stage 18 and wafer 16. Microscope 20 typically has a turret carrying several objective lenses ranging in power from 2.5X to 200X magnification and is mounted so that microscope 20 and camera 22 have a vertical optical axis which is perpendicular to the wafer surface.

During operation, the microscope turret (not shown) automatically rotates to place a low magnification objective lens into the optical path. A dedicated pattern recognition system then locates a feature to be measured on wafer 16 by moving stage 18 horizontally until the feature is in the field of view.

After the feature is located, an automatic focussing system focusses the optical system sufficiently for the pattern recognition system to locate the feature more precisely. The microscope turret then rotates to a higher magnification objective lens. Automatic focussing is repeated to obtain a fine focus at a desired plane.

After the optical system has been focussed, a focused image of the feature patterns is digitized and recorded by the camera 22. The image is then stored or "frozen" and enhanced by an image processing subsystem 28 to improve the signal-to-noise ratio.

The system is controlled by a computer 30. Coupled to the computer 30 are an image monitor 32 for display of the image recorded by the camera 22, a text screen 34 and a keyboard 36 (which constitute an input terminal for entering operator commands) and a disk drive 38 for storing system software and data.

Image processor 28 uses software algorithms to locate the edges of the selected feature and make a measurement. Computer 30 then displays the measurement data on screen 34, prints a hard copy or transfers the data directly to a host computer for centralized data analysis. Once the process is complete, wafer 16 is returned to cassette 12 by the wafer handler.

An illustrative critical dimension pattern is shown in Figs. 3A and 3B. A top view is shown in Fig. 3A, and a partial, cross-sectional view of wafer 16 with a portion of the etched pattern (finger 50) is shown in Fig. 3B. The pattern includes three "fingers" with a central finger 50. The line width of any of the fingers can be measured to determine if critical dimensions are within design specifications. As previously mentioned, the critical dimension measurement utilizes signal processing techniques which assume that the pattern lines are in sharp focus, consequently, if the pattern lines are not in sharp focus, a measurement variation will result.

More particularly, an enlarged view of the cross-sectional pattern diagram shown in Fig. 3B is illustrated in Fig. 3C. Ideally, sides 51 of pattern 50 would be vertical, but, in actuality, sides 51 are slanted, rough or rounded due to the etching process which is used to form the patterns on the surface of wafer 16. Suppose, for example, that it is desirable to measure the pattern width at a plane 53 above the surface 57 of wafer 16 with an accuracy of much less than the thickness of the pattern 50. In the prior art focussing systems, the portions of the feature edge which lie above and below plane 53 (such as portions 51 or 55) reduce the signal-to-noise ratio and introduce focussing variations because they inherently are present in the video image of the edge or are covered by the sensing spot. Further problems arise if the semiconductor layers are stacked and partially transparent. In these cases it may not be possible to determine at exactly what level the focussing system is actually focussed, thus a measurement uncertainty results.

In accordance with the invention, a three-step focussing sequence is used to ensure reliable focussing. In particular, during operation of the focussing system, the microscope turret is first adjusted for a low magnification (for example, 20X) in order to obtain a coarse focus. In order to obviate the previous inaccuracies resulting from the use of the etched feature patterns, a focussing pattern is projected through the microscope optical system directly onto the surface of the wafer. This latter pattern is then used for the focussing operation. The focussing pattern may be a knife edge, a line, a plurality of lines with equal or different widths, or may be a three-dimensional image which has several different focal planes.

Since the focussing image is projected onto the wafer surface and does not have a sloped edge, it avoids the focussing problems associated with focussing on etched features or developed photoresist patterns. Also, since the pattern may be projected onto a selected region of the microscope field of view, the level and the position at which the optical system is focussing can be precisely selected. Consequently, when the projected image is brought into focus, the features and patterns are also brought into sharp focus at the desired position. The optical system is then focussed, illustratively by using the aforementioned video-contrast maximization method.

Subsequently, the microscope turret is operated to increase the magnification, for example, to 100-200X to obtain more resolution. A focussing pattern is again projected onto the wafer surface and the focussing operation is repeated.

Finally, after the focussing operation has been completed, the projected image may be removed and the focussed feature images are used to make the process-control measurement.

More specifically, the optical focussing pattern is projected onto the wafer surface by placing an image source into the optical path of the microscope during the focussing process. For example, the image source may be simply a blackened knife edge (projecting a pattern shown in Fig. 7A), a wire stretched on a frame or a chromium line etched on a transparent glass substrate. Alternatively, a more complex image source may be formed of several spaced sub-image sources or a plurality of light-emitting devices arranged in a predetermined pattern either in two dimensions or three dimensions. Due to the magnification of the microscope optics, the image source dimensions need not be as precise as the focal distance achieved by the system. For example, an image source with grid lines spaced by 25 microns will project through the microscope optical system onto the wafer surface with grid lines spaced to 0.2 microns.

Fig. 4 shows a schematic diagram of the microscope optical system illustrating two alternative positions for placement of the image source in the optical system so that it projects a focussing pattern on the wafer surface. In the illustrative microscope optical system, illumination of the wafer surface is provided by a lamp 60 operating in conjunction with a condenser lens 62. Condenser lens 62 focusses the light generated by lamp 60 along path 61 to a field plane position 63 (a "field plane" is a location in the microscope optical system where a "field aperture" would be located. A field aperture is a position where a variable diaphragm may be placed to adjust the field of view of the microscope. This position may be in the illumination path). An object placed in the field plane is imaged at the object plane or the wafer surface. After passing through the field plane 63, the light passes along path 65 and is reflected from a beam splitter 68 located in the main optical path of the microscope. Light reflected from beam splitter 68 passes through objective lens 70 onto the surface of wafer 16.

Light reflected by the wafer surface and features passes back through the objective lens 70, through beam splitter 68 and along optical paths 69 and 67 to camera 22 which forms an enlarged image of the wafer surface.

In accordance with one aspect of the invention, an image source may be inserted in either location 64 or at another location, such as location 66, to project a focussing pattern onto the surface of wafer 16. Fig. 5A shows one embodiment of the block 64 which is suitable for use with a self-illuminated image source. Such an image source might, for example, be comprised of a plurality of light-emitting devices. In Fig. 5A, light from image source 72 which is directed by lens 74 to a beam splitter 76 located at the field plane 63. Beam splitter 76 causes an image of source 72 to be projected along optical path 65 through the aforementioned microscope optics to the wafer surface.

Fig. 5B shows an alternative embodiment of the block 64 in which a passively illuminated image source 72 is merely inserted at the field plane 63 of the illumination optical system. In this case, light from the illumination source passes through the image source and projects a pattern onto the wafer surface.

Fig. 6 shows an alternative location for the image source at the location of block 66 shown in Fig. 4. This latter embodiment is also suitable for use with a self-illuminated image source 72. Light generated by image source 72 is reflected from beam splitter 76 located in the main optical path of the microscope.

From there, the image of the source passes along optical path 69 through objective lens 70 to the wafer surface. In this latter embodiment, it may be necessary to shutter the normal microscope illumination system to increase the signal to the noise ratio of the projected focussing image. This location has the advantage that, if the optical distance between source 72 and beam splitter 76 is equal to the optical distance between camera 22 and beam splitter 76, then the focussing system is insensitive to variations in the microscope and can be easily adjusted to account for inaccurate camera alignment.

The structure which generates the focussing image can itself be mounted on a motorized stage so that it can be moved around over the wafer image. In this manner the focussing pattern can be precisely positioned over any feature on the wafer image on which focussing is desired. The image source stage may be controlled by computer 30 to move to predetermined positions on the wafer image before the focussing operation is initiated. As the details of the image source movement and control are conventional they are not described in detail herein.

Figs. 7A-7D show illustrative two-dimensional image source patterns which might be used with the invention. Although several illustrative image source patterns are shown in Fig. 7, many other source designs could, of course, be used in accordance with the invention. Further, in accordance with the invention, it is possible to select a pattern which produces an image that is unique and different from any patterns which might be encountered on the wafer surface. The system which focusses on the projected pattern can then more easily distinguish between the projected pattern and existing patterns on the wafer surface. In this manner it is possible to optimize the "signal-to-noise" ratio of the focussing procedure.

Figs. 8A and 8B show the top and side views of an illustrative three dimensional image source. Such an image source may be formed, for example, from three two-dimensional source lines or sub-image sources. These sub-image sources are then arranged along the optical axis form the three-dimensional image source. This image source has the property that when one of the three lines in the projected focussing pattern image is in focus, the other two line images (which are at different planes) will be out of focus as shown in Fig. 9. Consequently, the projected image pattern can be used to generate more focussing information than can be obtained from a two-dimensional source.

Illustratively, the three-dimensional source is positioned to project a focussing pattern onto the wafer so that the center line 82 is in, or near, focus at the desired plane at which measurements are to be taken. Then, the pattern generated by line 81 will be blurred (shown as pattern 95 in Fig. 9) since it lies above the desired plane and the pattern generated by line 83 will also be blurred (shown as pattern 97 in Fig. 9) since it lies below the desired plane. However, the image processing system which maximizes the contrast of image

96 in Fig. 9 to focus the optical system can use the additional information generated by images 95 and 97 to interpolate and calculate how far away from ideal focus image 96 is and how far to adjust stage 18 to bring the image 96 into focus. Consequently, precise focussing can be achieved much more rapidly than with a two-dimensional focussing pattern.

The image source shown in Figs. 8A and 8B also has the added advantage of having focal planes located at predetermined steps above and below the wafer surface. After making a measurement using the pattern 96 generated by line 82, the focussing system can be readjusted so that pattern 95 generated by line 81 is in focus. Then it is known that the wafer has been moved a predetermined distance. Thus, it is possible, using the Figs. 8A and 8B image source, to "step" the wafer by predetermined distances without relying on the accuracy of movement in stage 18. This operation leads to increased measurement accuracy and repeatability.

Although only one illustrative embodiment has been shown in the inventive focussing system, other modifications and changes will be immediately apparent to those skilled in the art. For example, although the invention has been described with respect to a semiconductor measurement system, the inventive apparatus and techniques can be applied to other types of measurement systems and to inspection systems which utilize an optical system. Such systems may, for example, measure and inspect features formed by etching and other process techniques. In addition, although only two locations are shown, with conventional optical path modifications, the image source can be inserted into the optical path at any point. In addition, rather than using a self-illuminated image such as would be generated by light-emitting devices, it is also possible to replace such devices with a non-illuminated image source in conjunction with a separate illuminator or optics which channel a portion of the light from the existing illuminator through the non-illuminated image source. These modifications and changes are intended to be covered by the following claims. Further, although the focussing method described involves projecting the focussing image so that it is in focus when the desired measurement plane is in focus, it is also possible to focus the system a known distance away from the desired plane and then move stage 18 that known distance in order to bring the desired plane into focus.

What is claimed is:

1. In an optical microscope system for forming an image of an object having a surface, apparatus for focussing said microscope in a plane positioned at a predetermined distance from said object surface, said apparatus comprising:

    means for projecting a focussing pattern image onto said plane; and

    means for controlling said microscope system to focus on said pattern image.

2. In an optical microscope system, the focussing apparatus according to Claim 1 wherein said optical microscope comprises an illumination system for projecting illumination light along an illumination path and through said microscope onto said wafer surface and said projecting means comprises means for introducing said focussing pattern image into said illumination path.

3. In an optical microscope system, the focussing apparatus according to Claim 1 wherein said projecting means comprises a plurality of image sources, said image sources being arranged to form a three-dimensional image source.

4. In an optical microscope system, the focussing apparatus according to Claim 3 wherein said controlling means controls said microscope system to focus on a first portion of said pattern image.

5. In an optical microscope system, the focussing apparatus according to Claim 4 wherein said controlling means is responsive to a second portion of said pattern image for controlling said microscope system to focus on said first portion of said pattern image.

6. In an optical microscope system, the focussing apparatus according to Claim 1 wherein said controlling means comprises means for maximizing the contrast of said pattern image.

7. In an optical microscope system, the focussing apparatus according to Claim 1 wherein said optical microscope comprises an optical path for developing a magnified image of said object and said projecting means comprises means for introducing said focussing pattern image into said optical path.

8. In an optical microscope system, the focussing apparatus according to Claim 1 wherein said focussing pattern is chosen so that it differs from any patterns present on said object surface.

9. In an optical measurement and inspection system for measuring and inspecting objects, said system having an optical microscope for forming an image of a feature on a surface of said object, means for automatically focussing said microscope on said feature image and means responsive to a focussed feature image for performing a measurement, the improvement comprising:

means for projecting a focussing pattern image onto said object surface, said focussing means being responsive to said projected pattern for focussing said projected pattern image.

10. In an optical measurement and inspection system, the improvement according to Claim 9 wherein said optical microscope comprises an illumination system for projecting illumination light along an illumination path and through said microscope onto said object surface and said projecting means comprises means for introducing said focussing pattern into said illumination path.

11. In an optical measurement and inspection system, the improvement according to Claim 10 wherein said illumination system comprises a lamp, a lens for focussing light generated by said lamp along said illumination path and a beam splitter for directing light passing along said illumination path onto said object surface and said introducing means comprises an image source located in said illumination path substantially at a field plane of said optical microscope.

12. In an optical measurement and inspection system, the improvement according to Claim 11 wherein said image source comprises a knife-edge.

13. In an optical measurement and inspection system, the improvement according to Claim 10 wherein said illumination system comprises a lamp, a condenser lens for focussing light generated by said lamp along said illumination path and a first beam splitter for directing light passing along said illumination path onto said object surface and said introducing means comprises means for generating an illuminated focussing pattern image, means for focussing said focussing pattern image onto a field plane of said microscope located in said illumination path and a second beam splitter located at said field plane for directing said focussing pattern image along said illumination path onto said object surface.

14. In an optical measurement and inspection system, the improvement according to Claim 13 wherein said focussing pattern image generating means comprises a plurality of light-emitting devices.

15. In an optical measurement and inspection system, the improvement according to Claim 9 wherein said projecting means comprises a plurality of image sources, said image sources being arranged to form a three-dimensional image source.

16. In an optical microscope system, the focussing apparatus according to Claim 15 wherein said focussing means focusses said microscope system on a first portion of said pattern image.

17. In an optical microscope system, the focussing apparatus according to Claim 16 wherein said focussing means is responsive to a second portion of said pattern image for focussing said microscope on said first portion of said pattern image.

18. In an optical measurement and inspection system, the improvement according to Claim 9 wherein said optical microscope comprises an optical path for transmitting a magnified image of said object surface to a camera and said projecting means comprises means for introducing said focussing pattern into said optical path.

19. In an optical measurement and inspection system, the improvement according to Claim 18 wherein said introducing means comprises means for generating an illuminated focussing pattern image, means for directing said focussing pattern image to a beam splitter located in said optical path for directing said focussing pattern image along said optical path onto said object surface.

20. In an optical measurement and inspection system, the improvement according to Claim 19 wherein said focussing pattern image generating means comprises a plurality of light-emitting devices.

21. An optical measurement and inspection system for measuring and inspecting features on an object, said system comprising:

an optical microscope having an optical system for forming an image of an edge of a feature on a surface of said object;

means for controlling said microscope optical system to automatically focus said feature edge image;

means for projecting a focussing pattern onto said object surface;

means responsive to said projected pattern for controlling said microscope optical system to focus said projected pattern whereby said feature edge image is also focussed; and

means responsive to a focussed feature edge image for performing a process control measurement.

22. A process-control measurement system according to Claim 21 wherein said optical microscope comprises an illumination system for projecting illumination light along an illumination path and through said microscope onto said object surface and said projecting means comprises means for introducing said focussing pattern into said illumination path.

23. A process-control measurement system according to Claim 22 wherein said illumination system comprises a lamp, a lens for focussing light generated by said lamp along said illumination path and a beam splitter for directing light along said illumination path onto said object surface and said introducing means comprises an image source located in said illumination path substantially at a field plane of said optical microscope.

24. A process-control measurement system according to Claim 23 wherein said image source comprises a knife edge.

25. A process-control measurement system according to Claim 23 wherein said image source comprises a plurality of sub-image sources, said sub-image sources being arranged along said illumination path.

26. A process-control measurement system according to Claim 22 wherein said illumination system comprises a lamp, a lens for focussing light generated by said lamp along said illumination path and a first beam splitter for directing light passing along said illumination path onto said object surface and said introducing means comprises means for generating an illuminated focussing pattern image, means for directing said focussing pattern image to said illumination path and a second beam splitter located in said illumination path for directing said focussing pattern image along said illumination path onto said object surface.

27. A process-control measurement system according to Claim 26 wherein said focussing pattern image generating means comprises a plurality of light-emitting devices.

28. A process-control measurement system according to Claim 21 wherein said microscope optical system comprises an optical path for transmitting a magnified image of said object surface to a camera and said projecting means comprises means for introducing said focussing pattern into said optical path.

29. A process-control measurement system according to Claim 28 wherein said introducing means comprises means for generating an illuminated focussing pattern image, means for directing said focussing pattern image to a beam splitter located in said optical path for directing said focussing pattern image along said optical path onto said object surface.

30. A process-control measurement system according to Claim 29 wherein said focussing pattern image generating means comprises a plurality of light-emitting devices.

31. A method for focussing an optical measurement and inspection system on features of an object, said system having an optical microscope having an optical system for forming an image of a feature on a surface of said object, said method comprising the steps of:
   A. controlling said microscope optical system to focus said feature image;
   B. projecting a focussing pattern onto said object surface; and
   C. controlling said microscope optical system to focus said projected pattern whereby said feature image is also focussed.

32. A method for focussing an optical measurement and inspection system according to Claim 31 wherein said optical microscope comprises an illumination system for projecting illumination light along an illumination path and through said microscope onto said object surface and step B comprises the step of:
    B1. introducing said focussing pattern into said illumination path.

33. A method for focussing an optical measurement and inspection system according to Claim 32 wherein said illumination system comprises a lamp, a condenser lens for focussing light generated by said lamp along an illumination path and a beam splitter for directing light passing along said illumination path onto said object surface and step B1 comprises the step of:
    B1A. placing an image source in said illumination path substantially at a field plane of said optical microscope.

34. A method for focussing an optical measurement and inspection system according to Claim 32 wherein wherein said illumination system comprises a lamp, a condenser lens for focussing light generated by said lamp along said illumination path and a beam splitter for directing light passing along said illumination path onto said object surface and step B1 comprises the step of:

B1B. placing a plurality of image sources arranged along said illumination path substantially at a field plane of said optical microscope.

35. A method for focussing an optical measurement and inspection system according to Claim 32 wherein said illumination system comprises a lamp, a lens for focussing light generated by said lamp along said illumination path and a first beam splitter for directing light passing along said illumination path onto said object surface and and step B1 comprises the steps of:

B1C. generating an illuminated focussing pattern image; and

B1D. directing said focussing pattern image along said illumination path onto said object surface.

36. A method for focussing an optical measurement and inspection system according to Claim 31 wherein said microscope optical system comprises an optical path for transmitting a magnified image of said object surface to a camera and step B comprises the step of:

B2. introducing said focussing pattern into said optical path.

37. A method for focussing an optical measurement and inspection system according to Claim 36 wherein step B2 comprises the steps of:

B2A. generating an illuminated focussing pattern image;

B2B. directing said focussing pattern image to a beam splitter located in said optical path; and

B2C. directing said focussing pattern image along said optical path onto said object surface.

38. In an optical measurement and inspection system for measuring and inspecting an object, said system having an optical microscope for forming an image of a feature edge on a surface of said object, means for automatically focussing said feature edge image and means responsive to a focussed feature edge image for performing a measurement, the improvement comprising:

means for projecting a focussing pattern image onto said object surface, said focussing pattern having a plurality of focal planes, a portion of said focussing pattern coming into focus at each of said plurality of focal planes, said focussing means being responsive to said projected pattern for focussing said portion of said projected pattern.

39. A method for focussing an optical measurement and inspection system for taking at least two separate measurements on an object, said system having an optical microscope having an optical system for

forming an image of an edge of a feature on a surface of said object, said method comprising the steps of:

A. controlling said microscope optical system to focus said feature edge image;
B. projecting a focussing pattern onto said object surface, said focussing pattern having a plurality of focal planes, a portion of said focussing pattern coming into focus at each of said plurality of focal planes;
C. controlling said microscope optical system to focus a first portion of said focussing pattern;
D. obtaining a first image of said feature with said optical system;
E. making a measurement using said first image;
F. controlling said microscope optical system to focus a second portion of said focussing pattern;
G. obtaining a second image of said feature with said optical system; and
H. making a second measurement using said second image.

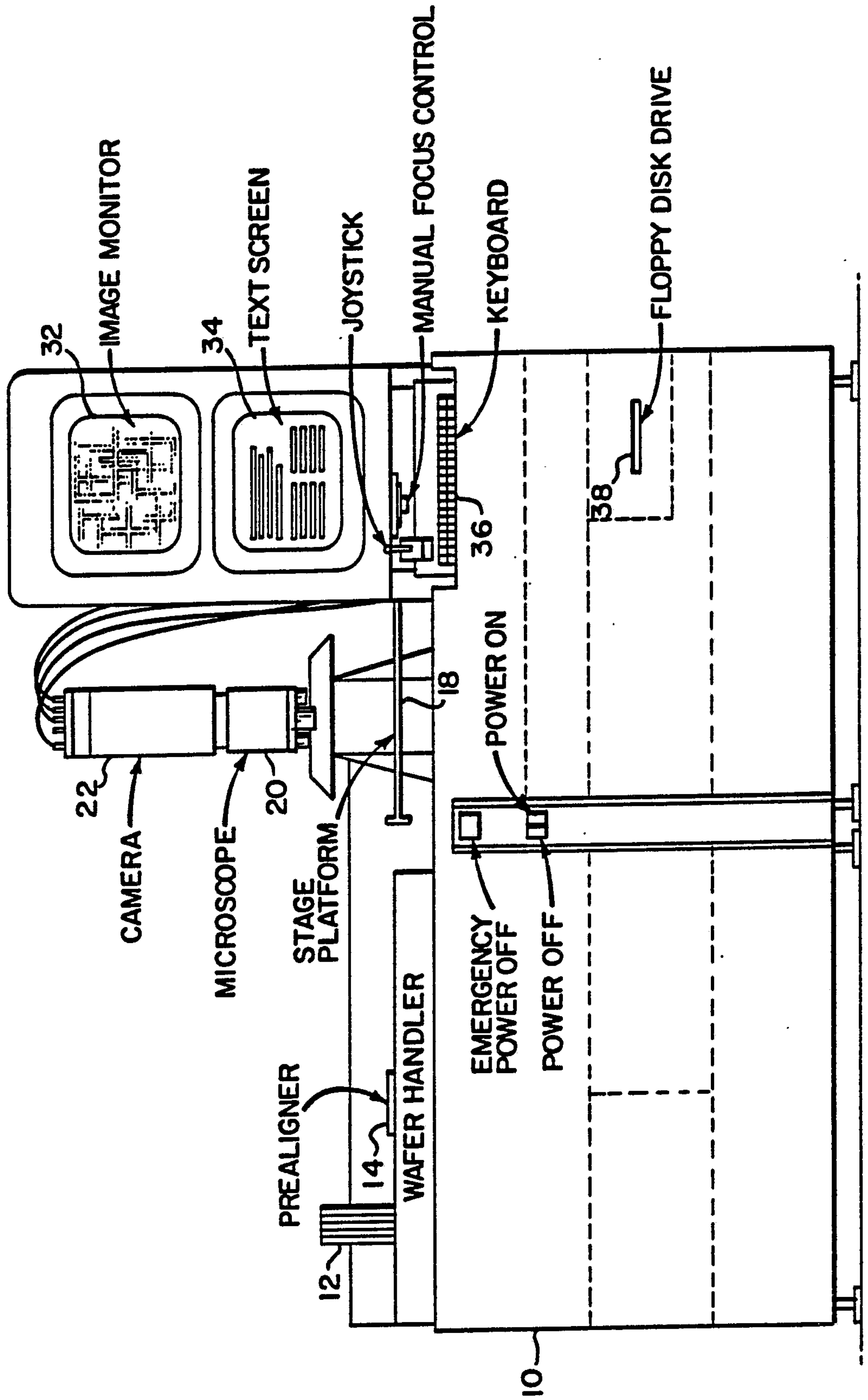


IMAGE MONITOR
32
TEXT SCREEN
34
JOYSTICK
MANUAL FOCUS CONTROL
KEYBOARD
36
FLOPPY DISK DRIVE
38
CAMERA
22
MICROSCOPE
20
STAGE PLATFORM
18
POWER ON
EMERGENCY POWER OFF
POWER OFF
PREALIGNER
14
WAFER HANDLER
12
10

Fig. 1

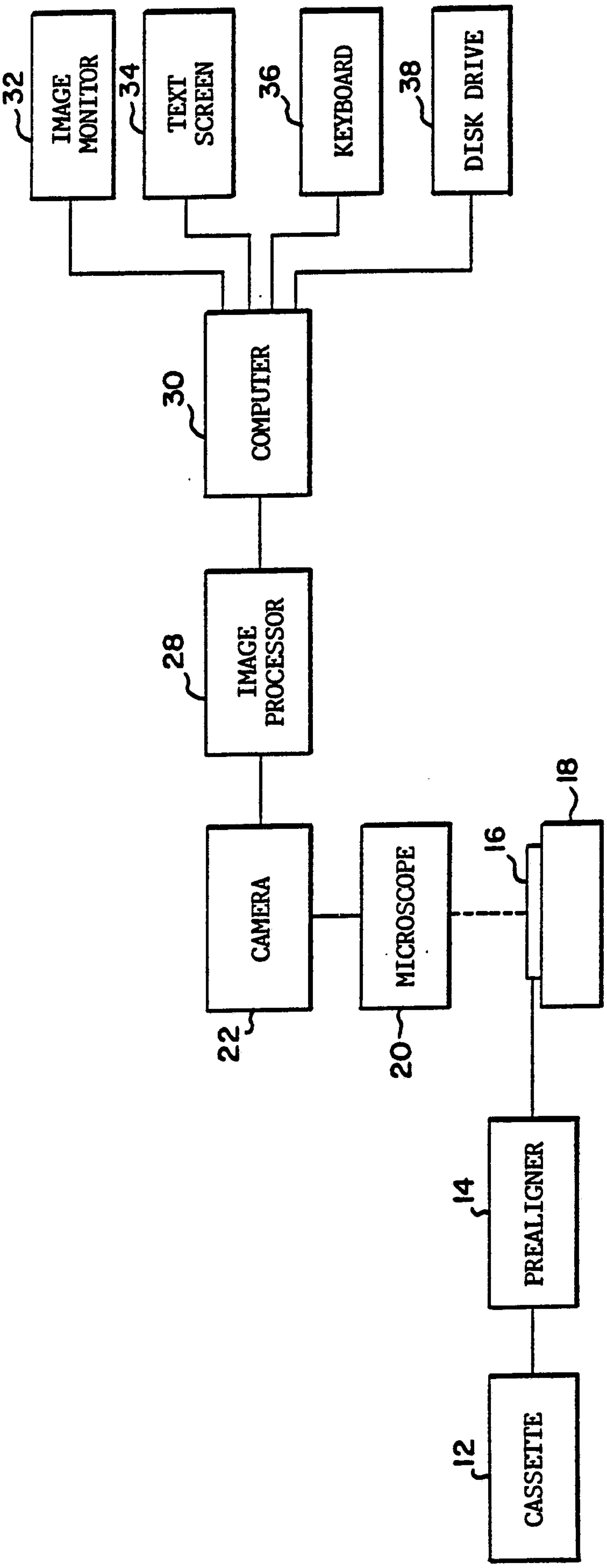


IMAGE MONITOR
32
TEXT SCREEN
34
KEYBOARD
36
DISK DRIVE
38
COMPUTER
30
IMAGE PROCESSOR
28
CAMERA
22
MICROSCOPE
20
16
18
PREALIGNER
14
CASSETTE
12

Fig. 2

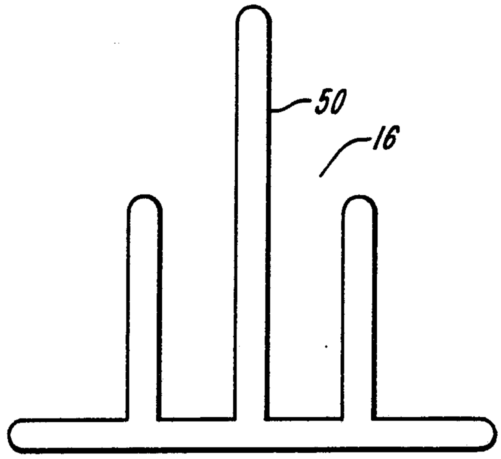


FIG. 3A

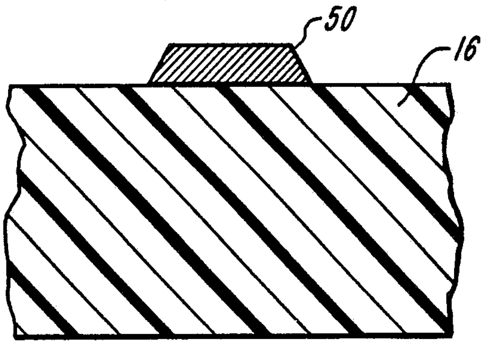


FIG. 3B

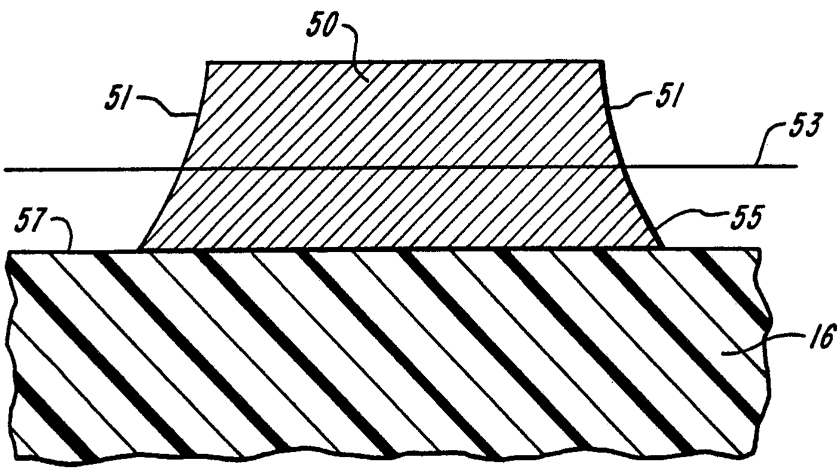


FIG. 3C

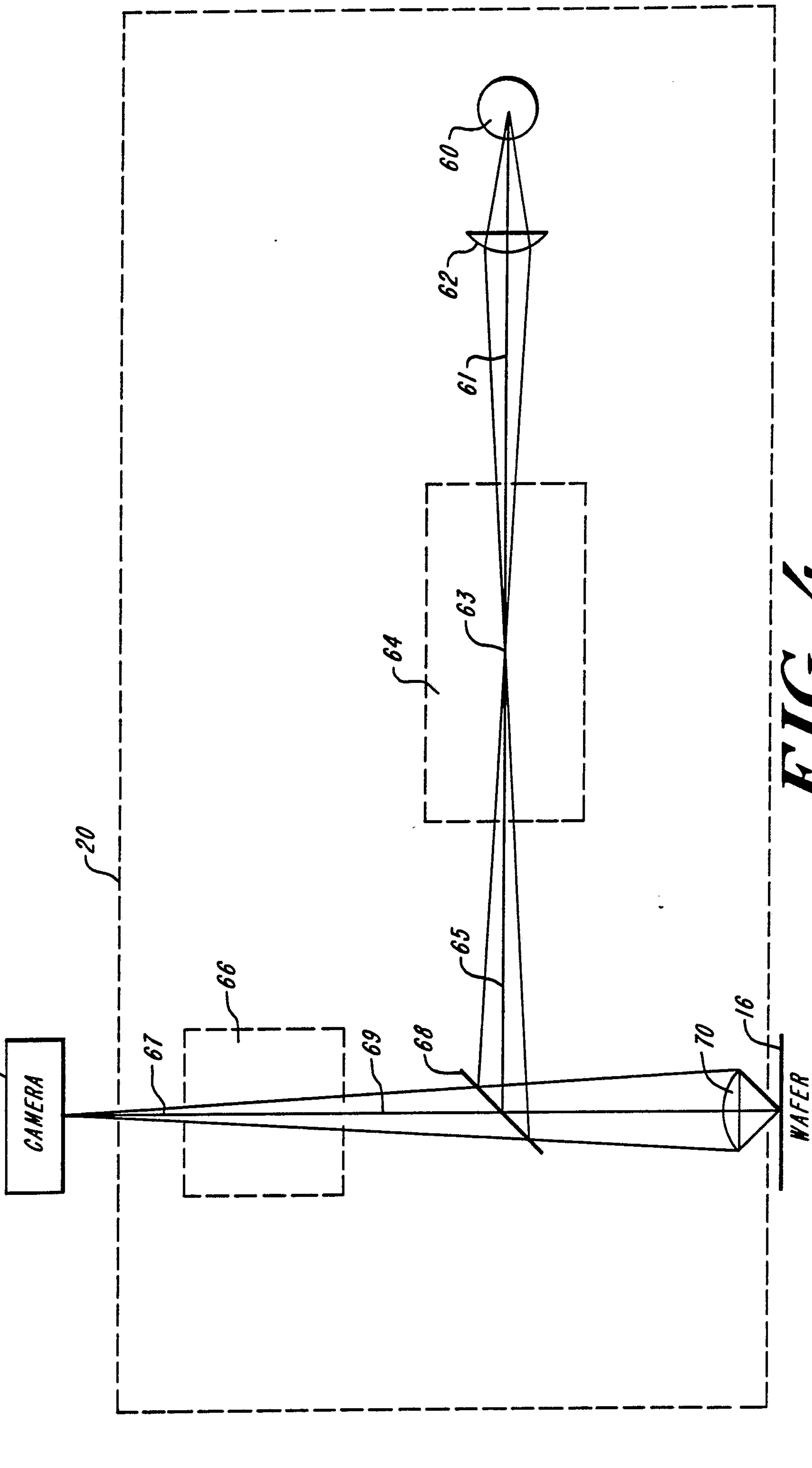


FIG. 4

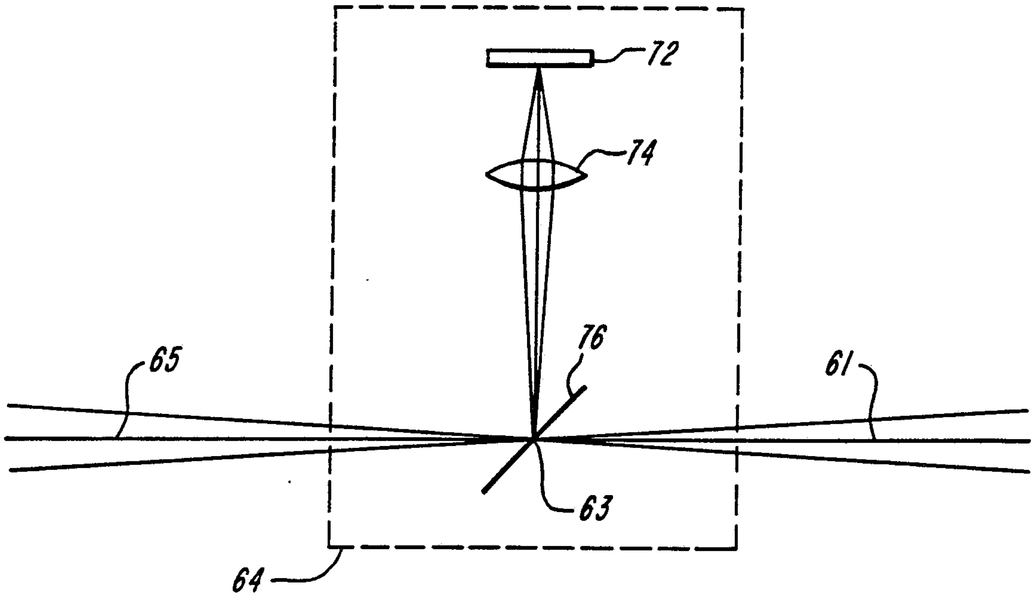


FIG. 5A

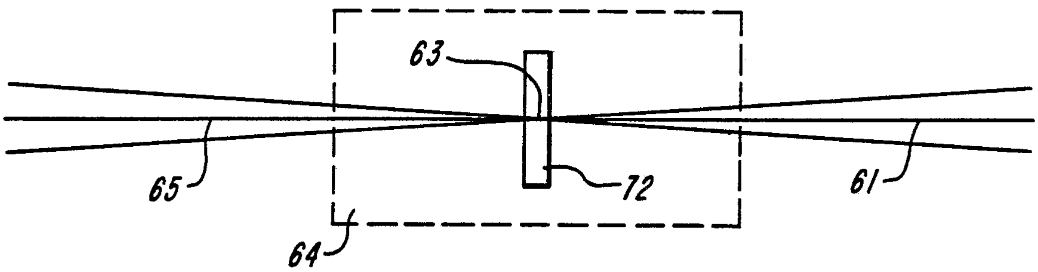


FIG. 5B

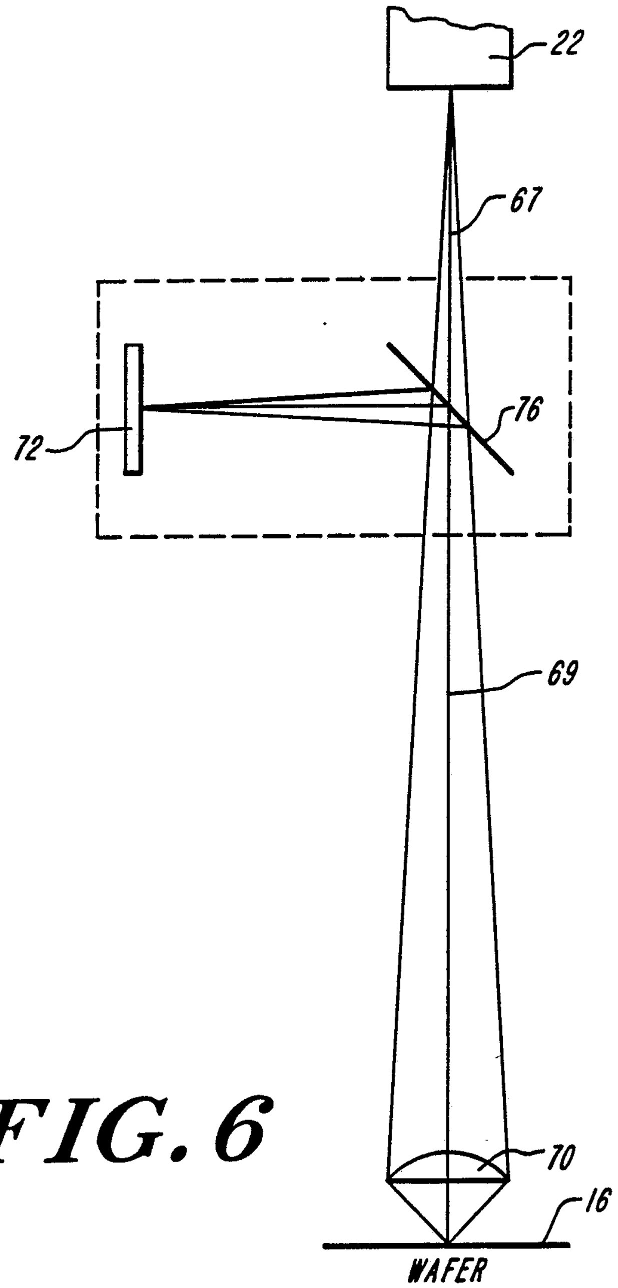


FIG. 6

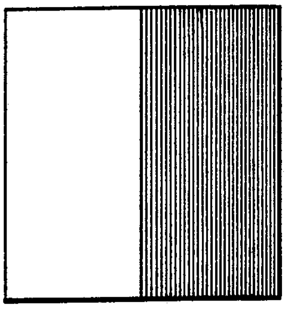


FIG. 7A

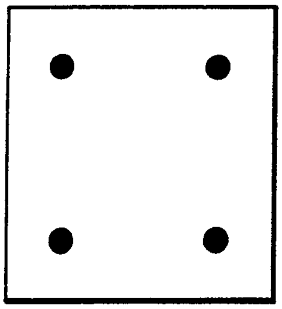
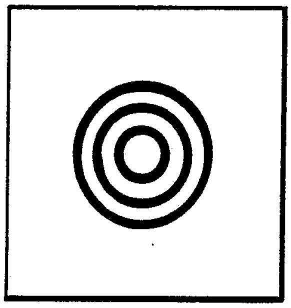


FIG. 7B

FIG. 7C



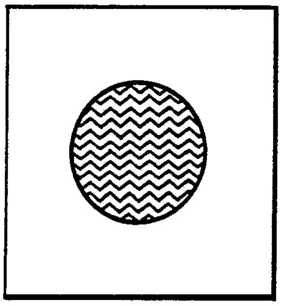


FIG. 7D

FIG. 8A

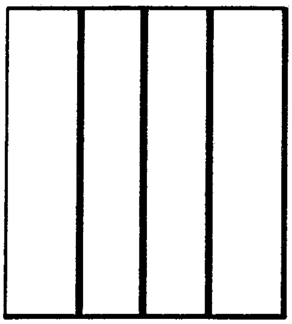


FIG. 8B

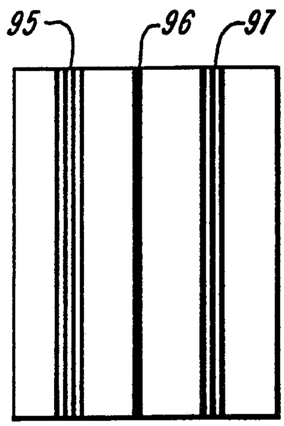


FIG. 9

INTERNATIONAL SEARCH REPORT

International Application No PCT/US 91/03536

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 G02B21/24

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
Int.Cl. 5	G02B ; H01L

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched[8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category °	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No.[13]
X	DE,A,3 739 223 (REICHERT-JUNG) June 1, 1989	1,2,6,7, 9-11,13, 18-23 26,28, 29,31-37
A	see abstract see column 1, line 10 - line 37 see claims 1-4,11,21,24-26,31,32,39; figure 1 ---	14-17, 24,27, 38,39

-/--

° Special categories of cited documents : [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

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

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

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

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
09 SEPTEMBER 1991	19 SEP 1991
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	LIPP G. Lipp

1

International Application No PCT/US 91/03536

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category °	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
X	DE,A,3 125 741 (SIEMENS) January 13, 1983	1,9,21, 31
A		12,18, 19,24, 28,29,37
	see abstract see page 4, line 2 - line 19 see page 7, line 7 - line 25; figure 2 ---	
X	PATENT ABSTRACTS OF JAPAN vol. 12, no. 271 (P-736)(3118) July 28, 1988 & JP-A-63 53 509 (TAMURON) March 7, 1988	1-3,5,9, 31
A		8,10-14, 19, 21-24, 26,27 29, 32-35, 37,39
	see the whole document ---	
X	PATENT ABSTRACTS OF JAPAN vol. 7, no. 168 (P-212)(1313) July 23, 1983 & JP-A-58 75 005 (HITACHI) May 6, 1983	1
A		3-9, 14-17, 20,21, 27,30 37-39
	see the whole document ---	

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO.

US 9103536
SA 48511

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the European Patent Office EDP file on 10/09/91
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE-A-3739223	01-06-89	None	
DE-A-3125741	13-01-83	None	

EPO FORM P0479

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82