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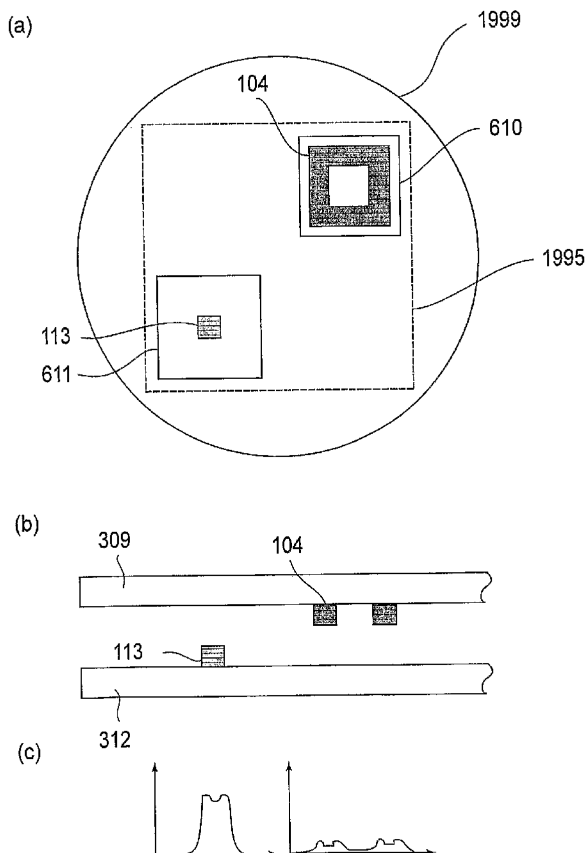

(57) Abstract: In an alignment method for effecting alignment between two plate-like objects, a first plate-like object provided with a first alignment mark and a second plate-like object provide with a second alignment mark are disposed opposite to each other. A first area and a second area are provided at mutually nonoverlapping positions in an image pickup area for being observed through an image pickup > device. Images of the first and second alignment marks are picked up by the image pickup device from a direction substantially perpendicular to an in-plane direction of the first and second plate-like objects. Alignment control is effected by using first information about a deviation of the first alignment mark from a predetermined position in the first area and second information about a deviation of the second alignment mark from a predetermined position in the second area.

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DESCRIPTION

ALIGNMENT METHOD, IMPRINT METHOD, ALIGNMENT APPARATUS, AND POSITION MEASUREMENT METHOD

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[TECHNICAL FIELD]

The present invention relates to an alignment method, an imprint method, an alignment apparatus, and a position measurement method.

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[BACKGROUND ART]

In recent years, as described in Appl. Phys. Lett., Vol. 67, Issue 21, pp. 3114 - 3116 (1995) by Stephan Y. Chou et al., a fine processing technology
15 for pressure-transferring a fine structure provided on a mold onto a work (or workpiece) such as a semiconductor, glass, resin, or metal has been developed and has received attention. This technology is called nanoimprint or nanoembossing since it has
20 resolving power on the order of several nanometers. In addition to semiconductor manufacturing, the technology is capable of effecting simultaneous processing of a three-dimensional structure at a wafer level. For this reason, the technology has been
25 expected to be applied to a wide variety of fields as manufacturing technologies and the like for optical devices such as photonic crystal and the like, μ-TAS

(micro total analysis system), biochips, etc.

The case where such nanoimprint, e.g., an optical imprint method is used in the semiconductor fabrication will be described below.

5 First, on a substrate (e.g., a semiconductor wafer), a resin layer of a photocurable resin material is formed. Next, against the resin layer, a mold on which a desired imprint pattern is formed is pressed, followed by irradiation with ultraviolet rays to cure 10 the photocurable resin material. As a result, the imprint structure is transferred onto the resin layer. Then, etching or the like with the resin layer as a mask is effected to form a desired structure on the substrate.

15 Incidentally, in the semiconductor manufacturing, it is necessary to effect (positional) alignment of the mold with the substrate. For example, in such a current circumstance that a semiconductor process rule is not more than 100 nm, a tolerance of 20 alignment error due to an apparatus is such a severe degree that it is said to be several nanometers to several tens of nanometers.

As such an alignment method, e.g., U.S. Patent NO. 6,696,220 has proposed a method in which a mold 25 and a substrate are caused to contact each other, in a state in which a resinous material is interposed therebetween, to effect alignment. In this method,

first, a photocurable resin material is selectively applied to a portion of the substrate other than an alignment mark provided to the substrate. Next, the substrate is moved to a position opposite to the mold. In this state, a distance between the mold and a work (the substrate provided with the photocurable material) is decreased so that the mold is caused to come near to such a distance that the alignment mark is not filled with the resin material. In the method, the alignment is effected in this state and thereafter final pressure application is performed. In the method, an optical system for alignment employs such an observation method that only a portion having a small depth of focus in the neighborhood of the alignment mark on the mold side is observed.

More specifically, the marks provided to the mold and the substrate, respectively, are formed into images in a single image pickup device by utilizing chromatic aberration.

However, references of the mold and the substrate are actually different from each other in many cases. In the case where the mark provided to the mold formed of quartz having a high transmittance and the mark provided to the substrate formed of silicon having a high reflectance overlap each other when the marks are projected in a perpendicular direction, the mold-side mark in a pickup image can be optically

blocked by the substrate-side mark.

In such a state, images of the alignment marks provided to the mold and the substrate, respectively, cannot be picked up with a sufficient gradation range, 5 so that a high detection resolution cannot be attained in some cases.

[DISCLOSURE OF THE INVENTION]

In view of the above described problems, a 10 principal object of the present invention is to provide an alignment method and an imprint method which are capable of solving the above described problems.

Another object of the present invention is to 15 provide an alignment apparatus and an imprint apparatus capable of carrying out the alignment method and the imprint method.

A further object of the present invention is to provide a position measurement method for measuring 20 a relative positional relationship of two objects or an amount of relative movement between the two objects.

According to a first aspect of the present invention, there is provided an alignment method for effecting alignment between two plate-like objects by 25 using a light source and an image pickup device, the alignment method comprising:

disposing a first plate-like object provided

with a first alignment mark and a second plate-like object provide with a second alignment mark opposite to each other;

providing a first area and a second area at mutually nonoverlapping positions in an image pickup area for being observed through the image pickup device;

picking up images of the first and second alignment marks by the image pickup device from a direction substantially perpendicular to an in-plane direction of the first and second plate-like objects;

effecting alignment control for aligning positions of the first and second plate-like objects in the in-plane direction with each other by using first information about a deviation of the first alignment mark from a predetermined position in the first area and second information about a deviation of the second alignment mark from a predetermined position in the second area; and

adjusting a gap between the first and second plate-like objects so that the gap is 3 μm or less by decreasing the gap while effecting the alignment control.

In the alignment method, each of the images of the first and second alignment marks picked up by the image pickup device may preferably be adjusted in contrast.

Further, by causing the first and second areas to have an identical planar area or the same number of pixels of the image pickup device, signal processing such as Fourier transform in a subsequent step is facilitated. Magnification correction of images observed in the first and second areas can be made depending on a change in magnification resulting from heights of the first and second plate-like objects.

According to a second aspect of the present invention, there is provided an alignment apparatus for effecting the above described alignment method.

The alignment apparatus comprises a first movable means for moving at least one of the first and second plate-like objects in the in-plane direction; and a second movable means for moving at least one of the first and second plate-like objects in a direction perpendicular to the in-plane direction.

According to a third aspect of the present invention, there is provided an imprint method for effecting alignment between two plate-like objects by using a light source and an image pickup device to imprint an imprint pattern provided to one of the two plate-like objects on the other plate-like object or a pattern forming layer formed on the other plate-like object, the imprint method comprising:

disposing a mold as a first plate-like object provided with a first alignment mark and a substrate

as a second plate-like object provide with a second alignment mark opposite to each other;

providing a first area and a second area at mutually nonoverlapping positions in an image pickup
5 area for being observed through the image pickup device;

detecting the first and second alignment marks by the image pickup device from a direction substantially perpendicular to an in-plane direction
10 of the first and second plate-like objects;

effecting alignment control for aligning positions of the first and second plate-like objects in the in-plane direction with each other by using first information about a deviation of the first
15 alignment mark from a predetermined position in the first area and second information about a deviation of the second alignment mark from a predetermined position in the second area; and

imprinting an imprint pattern provided to the
20 mold as the first plate-like object on the substrate as the second plate-like object or a pattern forming layer formed on the substrate.

According to a fourth aspect of the present invention, there is provided an imprint apparatus for
25 effecting an alignment method according to the third aspect of the present invention. The imprint apparatus comprises a first movable means for moving at least

one of the first and second plate-like objects in the in-plane direction; and a second movable means for moving at least one of the first and second plate-like objects in a direction perpendicular to the in-plane
5 direction.

According to fifth aspect of the present invention, there is provided an alignment method for effecting alignment between two plate-like objects by using an image pickup device. The alignment method
10 comprises:

disposing a first plate-like object provided with a first periodic structure with a pitch P1 as an alignment mark and a second plate-like object provide with a second periodic structure with a pitch P2 as an
15 alignment mark opposite to each other;

providing a first area and a second area at mutually nonoverlapping positions in an image pickup area for being observed through the image pickup device;

20 picking up images of the first and second periodic structures in the first and second areas, respectively, by the image pickup device from a direction substantially perpendicular to an in-plane direction of the first and second plate-like objects;

25 effecting alignment between the first and second plate-like objects in the in-plane direction by extracting basic frequencies corresponding to the

first and second periodic structures, respectively, from information about the picked up images, performing computation with the basic frequencies to extract a moire fringe component, and using
5 information about a positional deviation of the first and second plate-like objects in the in-plane direction obtained from the moire fringe component.

According to a sixth aspect of the present invention, there is provided a position measurement
10 method for measuring positions of two objects by using an image pickup device. The position measurement method comprises:

disposing a first object provided with a first periodic structure with a pitch P1 as an alignment
15 mark and a second object provide with a second periodic structure with a pitch P2 as an alignment mark opposite to each other;

providing a first area and a second area at mutually nonoverlapping positions in an image pickup
20 area for being observed through the image pickup device;

picking up images of the first and second periodic structures in the first and second areas, respectively, by the image pickup device from a
25 direction substantially perpendicular to an in-plane direction of the first and second objects;

effecting position measurement of the first

and second objects in the in-plane direction by extracting basic frequencies corresponding to the first and second periodic structures, respectively, from information about the picked up images, and performing computation with the basic frequencies to extract a moire fringe component.

According to a seventh aspect of the present invention, there is provided an imprint method comprising:

transferring a pattern formed on a processing surface of a mold onto a resin material provided on a surface of a substrate by curing the resin material,

wherein when an alignment mark provided to a mold is observed through an image pickup device, a wavelength of light entering the image pickup device depending on a gap between the mold and the substrate or a thickness of a member constituting the alignment mark.

According to an eighth aspect of the present invention, there is provided an alignment method for effecting alignment between two members by using an image pickup device. The alignment method comprises:

disposing a first member provided with a first alignment mark and a second member provide with a second alignment mark opposite to each other;

obtaining first image information about the first alignment mark in a first area in an image

pickup area for being observed through the image pickup device;

obtaining second image information about the second alignment mark in a second area, different from
5 the first area, in the image pickup area to be observed by the image pickup device;

performing computation of the first image information and the second image information; and

effecting alignment between the two members by
10 using the first image information and the second image information. In this alignment method, the computation may be performed by using the first image information and the second image information which are obtained at portions at which the first area and the second area
15 do not overlap each other.

According to an ninth aspect of the present invention, there is provided an alignment method for effecting alignment between two plate-like objects by using an image pickup device. The alignment method
20 comprises:

disposing a first plate-like object provided with a first periodic structure with a pitch P1 as an alignment mark and a second plate-like object provide with a second periodic structure with a pitch P2 as an
25 alignment mark opposite to each other;

providing a first area and a second area at mutually nonoverlapping positions in an image pickup

area for being observed through the image pickup device;

picking up images of the first and second periodic structures in the first and second areas, respectively, by the image pickup device from a direction substantially perpendicular to an in-plane direction of the first and second plate-like objects;

obtaining positional information about a relative position between the first and second plate-like objects by performing computation of image information obtained from the images picked up by the image pickup device; and

effecting alignment between the first and second plate-like objects in the in-plane direction by using the positional information.

These and other objects, features and advantages of the present invention will become more apparent upon a consideration of the following description of the preferred embodiments of the present invention taken in conjunction with the accompanying drawings.

[BRIEF DESCRIPTION OF THE DRAWINGS]

Figures 1(a) to 1(c) are schematic views showing a relationship between alignment marks for illustrating the present invention.

Figures 2(a) and 2(b) are schematic views for

illustrating a measurement optical system in the present invention, wherein Figure 2(a) is a view for illustrating a constitution in which light which reaches respective positions of an image pickup device is adjusted by an optical device, and Figure 2(b) is a view for illustrating a constitution in which light which reaches respective positions of an image pickup device is adjusted by a light source-side optical device.

Figures 3(a) and 3(b) are schematic views for illustrating rating a measurement optical system in the present invention, wherein Figure 3(a) is a view for illustrating a constitution in which light is adjusted by a light amount control apparatus, and Figure 3(b) is a view for illustrating a constitution in which light is adjusted by a rotary shutter.

Figures 4(a) to 4(d) are schematic views for illustrating marks used in the present invention, wherein Figure 4(a) shows a mold mark, Figure 4(b) shows a substrate mark, Figure 4(c) shows a mold mark having a periodic structure, and Figure 4(d) shows a substrate mark having a periodic structure.

Figure 5 is a schematic view showing an embodiment of a constitution of a mold applicable to the present invention.

Figures 6(a) and 6(b) are flow charts for illustrating a signal processing method in the present

invention, wherein Figure 6(a) is a flow chart for illustrating the case where magnification correction is not effected, and Figure 6(b) is a flow chart for illustrating the case where the magnification
5 correction is effected.

Figure 7 is a schematic view showing an embodiment of a constitution of an imprint apparatus for carrying out an imprint method according to the present invention.

10 Figure 8 is a schematic view showing an example of an image in the case where alignment marks provided to a mold and a substrate are observed through an image pickup device.

Figures 9(a) and 9(b) are schematic views
15 showing grating images in two areas.

Figure 10 is a schematic view for illustrating an embodiment of signal processing in the present invention.

Figure 11 is a schematic view for illustrating
20 phase deviation.

Figures 12(a) to 12(d) are schematic views for illustrating a method of alignment between a mold and a substrate by means of a reference substrate in Reference Embodiment 1 of the present invention,
25 wherein Figure 12(a) includes views for illustrating the case where observation is made in a state in which the reference substrate is disposed at a first object

position, Figure 12(b) includes views for illustrating the case where observation is made in a state in which the reference substrate is disposed at a second object position, Figure 12(c) includes views for illustrating the case where observation is made in a state in which the substrate is disposed at the second object position, and Figure 12(d) includes views for illustrating the case where observation is made in a state in which the substrate is disposed at the first object position.

Figures 13(a) to 13(c) are schematic views for illustrating a constitution of the reference substrate in Reference Embodiment 1.

Figure 14 is a schematic view for illustrating a measuring optical system in Reference Embodiment 1.

Figure 15 is a schematic view for illustrating a processing apparatus in Reference Embodiment 1.

Figures 16(a) to 16(c) are schematic views for illustrating a method of alignment between a mold and a substrate by means of a reference substrate in Reference Embodiment 2 of the present invention, wherein Figure 16(a) includes views for illustrating the case where observation is made in a state in which the reference substrate is disposed at a predetermined position, Figure 16(b) includes views for illustrating the case where observation is made in a state in which the substrate is disposed at the second object

position, and Figure 16(c) includes views for illustrating the case where observation is made in a state in which the substrate is disposed at the first object position.

5 Figures 17(a) to 17(d) are schematic views for illustrating a signal processing method in Reference Embodiment 3 of the present invention, wherein Figure 17(a) includes views for illustrating the case where observation is made in a state in which the reference substrate is disposed at a first object position,
10 Figure 17(b) includes views for illustrating the case where observation is made in a state in which the reference substrate is disposed at a second object position, Figure 17(c) includes views for illustrating
15 the case where observation is made in a state in which the substrate is disposed at the second object position, and Figure 17(d) includes views for illustrating the case where observation is made in a state in which the substrate is disposed at the first
20 object position.

Figures 18(a) to 18(f) are schematic views for illustrating alignment marks in Embodiment 3, wherein Figure 18(a) is a view for illustrating a first alignment mark for uniaxial measurement, Figure 18(b)
25 is a view for illustrating a second mark for uniaxial measurement, Figure 18(c) is a view for illustrating a composite image for uniaxial measurement, Figure 18(d)

is a view for illustrating a first alignment mark for XYθ measurement, Figure 18(e) is a view for illustrating a second alignment mark for XYθ measurement, and Figure 18(f) is a view for
5 illustrating a composite image for XYθ measurement.

Figures 19 and 20 are graphs each showing a relationship between a wavelength and intensity of light entering an image pickup portion.

10 [BEST MODE FOR CARRYING OUT THE INVENTION]

(First Embodiment)

An alignment method according to the present invention for effecting alignment between two plate-like objects by using a light source and an
15 image pickup device will be described with reference to Figures 1(a), 1(b) and 1(c).

Figure 1(a) is a top view for illustrating an image of an image pickup area 1995 observed through an image pickup device located in a visible range 1999 in
20 a body tube of a microscope. Figure 1(b) is a sectional view for illustrating a state of the two plate-like objects disposed opposite to each other when these plate-like objects are viewed in a direction parallel to an in-plane direction thereof.
25 Figure 1(c) includes line profiles of marks which are specifically described later.

In the alignment method, first, a first

plate-like object 309 provided with a first alignment mark 104 and a second plate-like object 312 provided with a second alignment mark 113 are disposed opposite to each other. In these cases, a first area 610 and a second area 611 are provided at mutually nonoverlapping positions in the image pickup area 1995 observed through the image pickup device. These two areas have been located within the image pickup area.

When images of the first and second alignment marks are picked up by the image pickup device from a direction substantially perpendicular to an in-plane direction of the first and second plate-like objects, an image as shown in Figure 1(a) is obtained.

Here, setting is made so that the alignment between the first and second plate-like objects is completed when the first alignment mark 104 of the first plate-like object 309 is located at a position of a center of gravity of or a center of the first area 610 and the second alignment mark 113 of the second plate-like object 312 is located at a position of a center of gravity of or a center of the second area 611. The completion of the alignment means that a desired condition (or degree) of the alignment between the two plate-like objects with respect to the in-plane direction of the two plate-like objects is satisfied. Actual alignment is effected in the following manner.

First information about a deviation of the first alignment mark from a predetermined position in the first area (e.g., the center of the first area) is obtained. Further, second information about a deviation of the second alignment mark from a predetermined position in the second area (e.g., the center of the second area) is obtained. The order of obtaining the first information and the second information is not particularly limited. The first information and the second information may also be obtained at the same time. Based on these two pieces of information, alignment control for aligning the first and second plate-like objects with each other in the in-plane direction is performed.

The alignment control may, e.g., be performed in the following manner.

First, in the case where driving mechanisms for driving (moving) the first and second plate-like objects, respectively, in the in-plane direction are provided, the alignment is effected so that each of the alignment marks for the first and second plate-like objects is located at the predetermined position.

Alternatively, either one of the two plate-like objects is fixed and the other plate-like object movable in the in-plane direction is moved in consideration of two pieces of information consisting

of information about a positional deviation of the other plate-like object and information about a positional deviation of the fixed plate-like object. For example, in the case where the position of the fixed first plate-like object is deviated from the predetermined position by 5 scales in a right direction in the first area and the position of the second plate-like object is deviated from the predetermined position by 2 scales in a left direction in the second area, the alignment is effected in the following manner.

The position of the second plate-like object is not moved in the right direction by 2 scales but is moved in the right direction by 7 scales (2+5 scales). This is merely an example.

In the case where the driving mechanism with respect to the in-plane direction is provided for only one of the first and second plate-like objects, positional adjustment is made by the above described manner.

Further, in the case where an optical axis of an optical system is movable, it is also possible to adopt correction of the optical axis by moving the optical system including a lens and the like into the alignment control.

When the positions of the first and second plate-like objects are adjusted at desired positions,

a distance (gap) between the first and second plate-like objects is gradually decreased while the alignment control (e.g., feedback control) is performed so as to maintain an adjusted positional relationship between the first and second plate-like objects in the in-plane direction. The first and second plate-like objects are brought near to each other so that the gap is 3 µm or less. In the case where the alignment method of this embodiment is applied to an imprint method, the gap may preferably be 1 µm or less.

Further, in the case where a photocurable or thermosetting resin material is interposed between the first and second plate-like objects and a pattern provided to the first plate-like object or the second plate-like object is transferred onto the resin material, the distance (gap) between the first and second plate-like objects may preferably be decreased to 300 nm or less, more preferably 200 nm or less, further preferably 100 nm or less. This is because a film having a thickness corresponding to the distance (gap) remains as a residual film after the resin material is cured or hardened.

In this embodiment, in the case where the first and second marks provided to the first and second plate-like objects, respectively, are observed, it is also possible to perform adjustment in contrast

of each of the first and second marks or to perform adjustment in SN ratio of each of the first and second marks.

Hereinbelow, the case where the first and second alignment marks of the first and second plate-like objects are observable by a single image pickup device, i.e., the case where both of the marks are located within the same depth of focus will be described.

Now, the case where marks of a mold and a substrate which are different in reflectance overlap each other is considered. In this state, when signal processing is performed, a sufficient contrast is not ensured to impede accurate measurement in some cases.

For example, in the case where the first plate-like object is a mold having an imprinting pattern, an alignment mark provided to the mold has an increased transmittance. For example, in the case where the mold is formed of quartz, the alignment mark is constituted by projections and recesses provided to the quartz mold. On the other hand, in the case where the second plate-like object as a substrate provided with an alignment mark is formed of, e.g., silicon, a contrast of the alignment mark of the mold (first plate-like object) is liable to be lower than the alignment mark of the substrate (second plate-like object) due to differences in transmittance and

reflectance between the alignment marks of the mold and the substrate. For this reason, the mold side mark can be optically blocked by the substrate side mark.

Accordingly, as in this embodiment, in the case where both of the marks are observed from the perpendicular direction, it is possible to adjust a contrast with respect to each of the mark images by disposing the respective mark observation areas at positions at which the areas does not optically affect each other.

The contrast may be adjusted by adjusting light entering the image pickup device by means of the optical system or by changing an exposure time for the image pickup device.

The reason why the marks are observed from the perpendicular direction is that a change in mark position due to movement of the mold or the substrate in an image pickup range of the image pickup device can be eliminated since the mold or the substrate is moved in z-(axis) direction (a direction perpendicular to the in-plane direction of the plate-like objects) when the imprint is effected. In the case of oblique observation, a signal processing method corresponding to a mark position change is required to be performed, thus complicating the imprint method.

Further, when the imprint is effected, different from a conventional exposure apparatus, a

gap between a mask and a substrate is not constant. For this reason, a magnification is changed with movement in the z-direction, so that signal processing depending on the change in magnification is required in some cases. Such signal processing is simpler in the case of the perpendicular observation since the change is isotropic.

Referring again to Figures 1(a) to 1(c), the description will be continued. In this embodiment, the mold as the first plate-like object and the substrate as the second plate-like object are disposed so as not to optically overlap each other.

Referring to Figure 1(a) (top view) and Figure 1(b) (sectional view), a first area A (610) and second area B (611) of the image pickup device are diagonally provided at corner portions. In the first area A (610) and the second area B (611), a mold-side alignment mark 104 and a substrate-side alignment mark 113 are adjusted in position so as to be disposed, respectively. The disposition (arrangement) of these two areas is not particularly limited so long as they do not optically overlap each other.

In the image pickup area 1995, a distance between the mold-side alignment mark and the substrate-side alignment mark is several tens of micrometers to several hundreds of micrometers. Further, a gap (distance in z-direction) between the

mold and the substrate is several micrometers. For this reason, even in consideration of numerical aperture of the microscope, the distance and the gap do not adversely affect the first area A and the second area B.

Accuracy of a stage is on the order of submicrometers or nanometers and sometimes on the order of subnanometers, so that it is possible to easily create such a state. Figure 1(c) illustrates a state when the marks on both of the mold and substrate sides are observed. More specifically, a left-hand view shows a line profile of the substrate-side alignment mark 113 (Figure 1(a)) and a right-hand view shows a line profile of the mold-side alignment mark 104 (Figure 1(a)), wherein an abscissa represents a position and an ordinate represents a light intensity. From these line profiles, it is found that the silicon substrate and the quartz mold have largely different reflectances. The marks have a line width of, e.g., subnanometers to several micrometers and a depth (height) of, e.g., several tens of nanometers to several micrometers. For this reason, the width and the depth of the marks can be less than a wavelength of light (e.g., 400 - 800 nm), so that edges of the marks are deformed compared with an original shape thereof to have such a shape that lower portions of the edges are trailed. In this embodiment in which

both of the marks are sufficiently spaced apart from each other, the marks do not adversely affect each other.

Other advantages of the case where the marks for the mold and the substrate are disposed in the separated areas and information about the marks is obtained as described above will be described.

In the case of effecting the imprint, it is necessary to effect the alignment between the mold and the substrate while decreasing the gap between the mold and the substrate. Even in the case where the marks are located within the depth of focus, an optical magnification changes depending on the height of the mold or the substrate. The charge is a serious problem in the imprint requiring high-accuracy alignment.

Even in such a case, when the mold and the substrate are sufficiently spaced apart from each other, it is possible to facilitate correction of magnification depending on the change in magnification. The magnification correction can be realized by comparing, e.g., the distance between the marks with an original designed value. In the case of the perpendicular observation, the magnification change is isotropic, so that the correction can be made easily. In the case of an oblique observation, sizes of the patterns on a close side and a distance side are

observed so as to be different from each other, so that the correction of magnification is complicated.

Figure 2(a) shows a constitution in which a contrast is adjustable depending on a position or place in an image pickup area of an image pickup device 3-7 of a CCD (charge coupled device) type or a MOS (metal-oxide-semiconductor) type. In front of the image pickup device 307, a first optical device 308 different in characteristic depending on the position is disposed. The optical device is constituted by a color filter, an interference filter, an ND (neutral-density) filter, a polarizer, and a combination thereof, or the like. Incidentally, as will be described in Fourth Embodiment appearing hereinafter, it is also preferable, from the viewpoint of an improvement in contrast, that a transmission wavelength range of a filter provided on a light source side or the image pickup device side is changed depending on the gap between the mold and the substrate. The constitution shown in Figure 2(a) includes a light source 301, an illumination optical system 302, a first beam splitter 303, a first image-forming optical system 304, a second image-forming optical system 306, a mold 309 provided with an imprinting pattern and an alignment mark 310, a substrate 312 such as silicon wafer provided with an alignment mark 311, and a first object position 313.

Figure 2(b) shows another constitute in which a contrast is adjustable depending on a position or place in an image pickup area of an image pickup device 307. In this constitution, a first optical device different in characteristic depending on the position is disposed on a light source side. The optical device is constituted by a color filter, an interference filter, an ND filter, a polarizer, and a combination thereof, or the like.

Figure 3(a) shows a constitution of an optical system in which a light amount control mechanism 901 for adjusting an amount of light in correspondence with each of marks for the mold and the substrate is used in order to effect contrast adjustment. As a result, the light amount control can be performed depending on reflectances or the like of the mold and the substrate. In this constitution, images of the mold mark and the substrate mark are separately picked up, so that it is necessary to pickup the images two or more times at a first amount of light and a second amount of light. An explanation of the constitution common to the constitution shown in Figures 2(a) and 2(b) will be omitted.

Figure 3(b) shows a constitution in which a rotary shutter 902 for changing an amount of light from the light source 301 is used. Depending on reflectances of the mold and the substrate at their

mark positions, a shutter position of the rotary shutter 902 is switched. Also in this constitution, it is necessary to pick up the images two or more times. The image pickup operation may be effected by changing
5 the light amount as described above or changing an exposure time or gain of the image pickup device 307 depending on characteristics of the mold and the substrate.

Figures 4(a) and 4(b) show examples of marks
10 used in a box-in-box type alignment method for effecting alignment between the mold and substrate.

In these figures, a mold-side alignment mark 104 is provided in a first area A (610) and a substrate-side alignment mark 113 is provided in a
15 second area B (611). In the case of using a single image pickup device, an image of the first and second areas is picked up as shown in, e.g., Figure 1(a).

Then, image data in the first and second areas are obtained from the image pickup device and, as
20 desired, are subjected to signal processing for obtaining profile data of intensity of reflected light. During the alignment, positions of the mold and the substrate in their in-plane directions are adjusted so that the respective alignment marks are located at
25 predetermined positions (e.g., positions of center of gravity or center positions) in the respective areas. Alternatively, it is also possible to effect the

alignment so that an amount of relative deviation between the mold and the substrate obtained from superposed (overlaid) images which are prepared by electronically superposing two images is decreased.

5 The above described alignment method of First Embodiment is applicable to not only the imprint apparatus but also a contact exposure apparatus and a proximity exposure apparatus. Further, in an apparatus capable of course adjustment and fine adjustment, the 10 course adjustment is made by a known alignment method and then the fine adjustment may be made by the above described alignment method.

In the case where two image pickup devices for picking up images in the first and second areas are 15 used, information about a difference between the two image pickup areas is obtained in advance by using a standard (reference) substrate or the like as in Reference Embodiments described later in order to perform compensation of the areas to be subjected to 20 image pickup by the respective image pickup devices.

(Second Embodiment: imprint method)

An imprint method of Second Embodiment will be described.

In this embodiment, the alignment between the 25 two plate-like objects is effected by using the image pickup device(s) similarly as in First Embodiment described above.

In this embodiment, imprint (transfer of an imprinting pattern) is performed so that an imprint pattern provided to one object is onto the other object or a pattern forming layer provided on the other object. In an actual operation, the imprinting pattern of a mold as one object is formed on the pattern forming layer as a reverse pattern thereof.

First, the mold as a first plate-like object having a first alignment mark and a substrate as a second plate-like object having a second alignment mark are disposed opposite to each other.

At a mutually nonoverlapping position in an image pickup area observed through an image pickup device, a first area and a second area are provided and then the first and second alignment marks are detected by the image pickup device from a direction substantially perpendicular to in-plane directions of the two plate-like objects.

Thereafter, first information about a deviation of the first alignment mark from a predetermined position in the first area and second information about a deviation of the second alignment mark from a predetermined position in the second area are utilized. More specifically, on the basis of the two pieces of information, alignment control for aligning the first and second plate-like objects with each other with respect to the in-plane direction is

effected.

Then, the imprinting pattern of the mold as the first plate-like object is transferred (imprinted) onto the substrate as the second plate-like object or 5 the pattern forming layer on the substrate.

During the imprint, a pressing force is required in the case of direct contact between the substrate and the mold. In the case where a resin material is interposed between the substrate and the 10 mold and used as the pattern forming layer, the pressing force may be applied as desired.

A) Mold

As the mold used in this embodiment, it is possible to employ a mold of quartz or a mold of 15 silicon nitride.

Further, as a material for a surface layer of the mold, it is also preferable that the material is constituted in the following manner.

More specifically, as the material for the 20 surface layer, by utilizing a material having a refractive index larger than 1.7, the alignment structures provided to the mold and the substrate (or a work) can be detected based on the difference in refractive index between the material and the 25 photocurable resin material to permit the high-accuracy alignment.

The refractive index of the surface layer in

the present invention is not less than 1.7, preferably not less than 1.8, more preferably not less than 1.9. Further, the refractive index may, e.g., be not more than 3.5 (upper limit). However, the upper limit of
5 the refractive index is not restricted so long as the resultant mold is usable in the present invention.

Further, in the case where a part of the surface layer has the above-described refractive index, the surface layer may also be coated with another
10 layer.

Generally, between substances having refractive indices largely different from each other, it is possible to visually recognize a structure based on refraction, reflection, or scattering at an
15 interface therebetween. Accordingly, a contrast is more liable to be ensured as the refractive index of the surface layer of the mold is higher.

The upper limit of the refractive index is not particularly limited as described above. Examples of
20 refractive index of representative dielectric members through which ultraviolet light passes may include 1.43 for calcium fluoride (CaF_2), 1.45 for quartz (typically represented by SiO_2), 1.78 for alumina (typically represented by Al_2O_3), 2.0 for silicon
25 nitride (SiN), and approximately 2.4 for titanium oxide (typically represented by TiO_2). Examples of transmittances of these substances with respect to

ultraviolet light of, e.g., a wavelength of approximately 365 nm may include approximately 97 % for CaF_2, approximately 90 % for SiO_2, approximately 80 % for Al_2O_3, approximately 60 % for TiO_2, and
5 approximately 90 % for SiN. The upper limit of refractive index of the surface layer-constituting material is not more than 3.5, preferably not more than 3.0. The refractive index itself varies depending on a measurement wavelength but the above described
10 data about the refractive index are those with respect to visible light (wavelength: 633 nm).

An embodiment of a constitution in which a material having a high refractive index is used as the surface layer of the mold as described above is shown
15 in Figure 5.

Referring to Figure 5, the mold includes a layer 5510 formed of quartz (SiO_2) (thickness: 525 μm) and a surface layer 5000 formed of the high refractive index material such as SiN or TiO_2. The surface layer
20 may have a thickness of, e.g., 50 nm for SiN and 60 nm for TiO_2. By using the high refractive index material, it is possible to obviate such a phenomenon that the alignment mold for the mold is less visible by the resin material interposed between the mold and the
25 substrate.

B) Substrate

The above described substrate is also called a

work in the imprint apparatus in some cases.

Examples of the substrate may include a semiconductor substrate such as an Si substrate (Si wafer) or a GaAs substrate; a resinous substrate; a quartz substrate; a glass substrate. It is also possible to use a multi-layer substrate prepared in such a manner that a thin film is caused to grow on these substrates or bonded to these substrates. It is also possible to employ a light transmissive substrate of quartz.

C) Resin material

In order to interpose the resin material between the substrate and the mold, e.g., the resin material is applied onto the substrate by a dispenser.

The resin material applied onto the substrate is cured by irradiating the substrate with, e.g., ultraviolet rays from the mold side. Example of such a photocurable resin may include those of urethane-type, epoxy-type, and acrylic-type.

Further, as the resin material, it is also possible to use a thermosetting resin such as a phenolic resin, an epoxy resin, a silicone resin, or polyimide, and a thermoplastic resin such as polymethyl methacrylate (PMMA), polycarbonate (PC), polyethylene terephthalate (PET), or acrylic resin. By using these resins, the pattern is transferred through heat treatment as desired.

In the case where the member to be processed (substrate) is constituted without containing the resin material, the member to be processed is physically deformed only by a pressing force.

5 (Third Embodiment: electronic generation of moire fringes)

Third Embodiment of the present invention will be described.

More specifically, an alignment method of
10 effecting alignment between two plate-like objects by using an image pickup device will be described.

First, a first plate-like object having a first periodic structure with a pitch P_1 as an alignment mark and a second plate-like object having a
15 second periodic structure with a pitch P_2 as an alignment mark are disposed opposite to each other.

Then, similarly as in First Embodiment, a first area and a second area are provided at mutually nonoverlapping positions in an image pickup area to be
20 observed through the image pickup device.

By using the image pickup device, images of the first and second periodic structures are picked up in the first and second areas, respectively, from a direction substantially perpendicular to an in-plane
25 direction of the first and second plate-like objects.

From image information obtained by picking up the image, basic frequencies corresponding to the

first and second periodic structures, respectively, are extracted.

Further, by computing the extracted basic frequencies, a moire fringe component is extracted.
5 From the extracted moire fringe component, information about positional deviation between the first and second plate-like objects with respect to the in-plane direction. By using this information, alignment between the first and second plate-like objects with
10 respect to the in-plane direction is effected.

A specific explanation will be made below.

In the following description, the case of using a quartz mold as the first plate-like object and a wafer substrate such as silicon wafer as the second
15 plate-like object is explained as an example. However, it should be understood that the present invention according to this embodiment does not exclude plate-like objects other than such plate-like objects.

Figures 4(c) and 4(d) are schematic views each
20 showing a constitution in which an alignment mark for the mold or the substrate is constituted by a grating. Referring to Figure 4(c), in a first area 610, a first periodic structure 701 (e.g., projections or recesses) with a pitch P_1 is provided as a mold-side alignment
25 mark to be observed through the image pickup device. Further, referring to Figure 4(d), in a second area 611, a second periodic structure 702 (e.g.,

projections or recesses) with a pitch P_2 is provided as a substrate-side alignment mark to be observed through the image pickup device.

Signal processing for extracting basic frequencies corresponding to the first and second from image information obtained from the image pickup device, extracting the above described moire fringe component, and obtaining information about positional deviation from the moire fringe component will be described below.

A signal processing method will be described with reference to Figures 6(a) and 6(b) showing flow charts for illustrating the signal processing method.

Figure 6(a) is a flow chart for illustrating the case where magnification correction is not effected.

Referring to Figure 6(a), images of the first area A and the second area B which are observed by a single image pickup device are obtained in step S-1. These two areas may desirably be areas in which images in these areas do not overlap each other but may also partially overlap each other so long as the two areas include different portions at which the images are located. It is desirable that the first area A and the second area B have the same size (area). This is because in many cases, the number of sampling for TFT (fast Fourier transform) analysis in the first area A

is equal to that in the second area B.

In the case where the area of the first area A is different from that of the second area B, such a processing that data at a peripheral portion are extended as they are so as to cause the first and second areas A and B to have the same area may appropriately be performed.

Next in Step S-2, signal processing A is effected in the first area A and signal processing B is effected in the second area B. Each of the signal processings A and B is ordinary filtering using a low-pass filter, a high-pass filter, a band-pass filter, an FFT-filter, a smoothing filter, a differential filter, etc. Further, gain adjustment is effected so as to optimize a contrast depending on the reflectances of the mold and the substrate and the like factor. This Step S-2 can also be omitted. More specifically, it is also possible to directly perform computation in Step S-3 after image information is obtained from the mutually different areas.

Incidentally, as will be described in Fourth Embodiment appearing hereinafter, it is also preferable, from the viewpoint of an improvement in contrast, that a transmission wavelength range of a filter provided on a light source side or the image pickup device side is changed depending on the gap between the mold and the substrate.

Next, in step S-3, computation is performed. The computation may be performed by effecting addition of images, multiplication of images, calculation of a difference between images, or calculation of images using other functions.

Next, in Step S-4, signal processing C is performed by using a filter similar to those used in step S-2.

Finally, in step S-5, detection of a position is made.

Incidentally, in the case where image data with respect to the respective areas are obtained by using different image pickup devices, as will be described in Reference Embodiments appearing hereinafter, information about a desired alignment completion condition is obtained in advance by using a standard substrate as a reference substrate.

Figure 6(b) is a flow chart showing the case where the step S-2 in the case shown in Figure 6(a) is divided into step S-21 for performing magnification correction and step S-22 for performing signal processing A and signal processing B. Particularly, in the imprint, a height of the mold or the substrate is changed. In correspondence therewith, an optical magnification is also changed. In such a case, there is a possibility that high-accuracy alignment cannot be effected when magnification correction is not made.

A method of making the magnification correction may, e.g., be one wherein a distance between adjacent bars is compared with a designed value thereof and a coefficient is changed so that the distance coincides
5 with the designed value. Incidentally, the signal processings in the step S-2 and the subsequent steps may be performed by using two-dimensional data or by converting the two-dimensional data into one-dimensional data.

10 In this embodiment, the case of using the two (first and second) areas is described but it is also possible to use three or more areas.

Next, an example of signal processing in the case where the mold mark shown in Figure 4(a) and the
15 substrate mark shown in Figure 4(b) are used will be described.

First, in the step S-1, images of the area A and the area B are obtained. In the step S-2, magnification correction and filtering using the
20 smoothing filter in each of the area A and the area B are effected to reduce noise. Further, contrasts of the areas A and B are adjusted. In the step S-3, the images of the areas A and B after the signal processing are added. This state is similar to that in
25 the case of optical overlaying (superposition). In the step S-4, further signal processing using the smoothing filter or the like is effected. In the step

S-5, the position is detected.

Incidentally, as the method of signal processing, it is also possible to directly determine centers of gravity of the marks in the areas A and B in the step S-2. Further, in the step S-3, a difference between the centers of gravity is calculated. In the step S-4, the signal processing is not particularly effected. In the step S-5, the difference is converted into a distance between the mold and the substrate. A condition of completion of the alignment is such that the difference is zero. The method described above may also be applicable to this embodiment.

Next, an example of signal processing in the case where the mold mark having a periodic structure shown in Figure 4(c) and the substrate mark having a periodic structure shown in Figure 4(d) are used will be described.

First, in the step S-1, images of the areas A and B are obtained. In the step S-2, magnification correction and conversion of two-dimensional data into one-dimensional data by effecting averaging processing are made. Further, by using the FFT filter, components of basic frequency of the periodic structures are obtained. In the step S-3, the resultant values are multiplied mathematically. This multiplication is represented by the following equation.

$$\sin(\frac{2\pi}{P_1}x)\times\sin\{\frac{2\pi}{P_2}(x+\delta)\}=\frac{1}{2}[-\cos\{\frac{2\pi}{P_1}x+\frac{2\pi}{P_2}(x+\delta)\}+\cos\{\frac{2\pi}{P_1}x-\frac{2\pi}{P_2}(x+\delta)\}]$$

In the above equation, δ represents a positional deviation and the second term of the right side represents a component of moire fringes. In the above equation, for the sake of simplicity, only the case where the positional deviation δ is added with respect to the period P2 is shown. Accordingly, it is also possible to add the positional deviation δ with respect to the period P1. Incidentally, in the alignment, it is important that information about relative positional deviation between the two objects. Further, it is also possible to utilize preliminarily determined known values without extracting the pitches P1 and P2 from image information when the components of basic frequency of the periodic structures are obtained.

In the step S-4, by the FFT, it is possible to simply divide the right side into the first term representing a low-frequency component and the second term representing a high-frequency component. As a result, as the component of moire fringes, the following term can be extracted.

$$\cos\{2\pi(\frac{1}{P_1}-\frac{1}{P_2})x-\frac{2\pi}{P_2}\delta\}$$

In the step S-5, the following phase component is extracted.

$$-\frac{2\pi}{P_2}\delta$$

From the phase component, it is possible to detect δ associated with the position.

In the alignment (positional adjustment), a condition of completing the alignment is taken as a time at which the phase component is zero in many cases.

Incidentally, as the grating-type marks, it is possible to use the grating-type marks 703 and 704 shown in Figures 18(a) and 18(b) with different pitches. More specifically, these marks are disposed in parallel to each other and from each of basic frequencies of the gratings, two sets of moire fringes with the same pitch are generated. By using the these moire fringes, it is also possible to effect the alignment between the mold and the substrate. In this case, marks with pitches P_1 and P_2 are disposed on the substrate so as not to overlap each other, and marks with pitches P_1 and P_2 are disposed on the mold so as not to overlap each other. It is preferable that two sets of moire fringes are generated by a combination of the substrate-side grating with pitch P_1 and the mold-side grating with pitch P_2 and a combination of the mold-side grating P_1 and the substrate-side grating with pitch P_2 as shown in Figure 8. The biggest advantage of such generation of the two sets of moire fringes is that it is possible to cancel

relative displacement between an image pickup object and the image pickup device. The generation of the two sets of moire fringes is also preferable in such a respect that the displacement is doubled in value.

5 Incidentally, as is understood from the above equation, the phase component is proportional to the displacement. Accordingly, it is possible to linearly measure a positional displacement between the mold and the substrate. This results in that it is generally 10 possible to linearly measure a relative position displacement between two planes. The present invention (according to the above described sixth aspect) also includes measurement with respect to such positions of two objects (e.g., measurement of an amount of 15 relative movement in the in-plane direction or measurement of the respective positions themselves).

Examples of application of the position measurement method, may include a linear scale for measuring a position of a stage.

20 Incidentally, an ordinary box-in-box type alignment mark is constituted so as to have a high sensitivity at zero point. Accordingly, as the mark for use in the position measurement method described above, the above described grating-type alignment mark 25 is suitable for the linear measurement. Further, the two objects employed in the measurement method generally include a plate-like object. However, the

two objects are not particularly limited to the plate-like object so long as it is provided with the above described alignment mark. For example, the two objects may be a combination of an object having a curved surface and a plate-like object.

Further, in this embodiment, the moire fringes are generated by the combination of two gratings but may also be generated by numerically multiplying the image pickup result of the alignment mark 701 with pitch P_1 by a sine wave with pitch P_2. Further, it is also preferable that the image pickup result of the alignment mark 701 with pitch P_1 is multiplied by a sine wave with pitch P_1 and a constant component is extracted with a filter to detect a phase.

Incidentally, an essential difference between the overlaying (superposition) of patterns such as a grating pattern or the like in the signal processing described in this embodiment and optical overlaying (superposition) will be described below.

The former (signal processing) overlaying is an ideal state but the latter (optical) overlaying is adversely affected by multiple reflection or the like. Particularly, in the case where the mold and the substrate have different reflectances, the optical overlaying is adversely affected by the multiple reflection. Accordingly, depending on a detection algorithm, an error can occur in measurement in the

case where the two marks are actually overlaid optically. For this reason, as in the present invention, it is possible obtain ideal signals to result in a less occurrence of error by using mutually nonoverlapping areas when the areas are observed from the perpendicular direction.

In this embodiment, at the time when components of basic frequencies of the first and second periodic structures is extracted through the FFT filter from the image data corresponding to the first and second periodic structures, it is possible to determine an amount δ of positional deviation between the mold and the substrate. Accordingly, it is also possible to effect positional adjustment without further performing the computation (S-3 shown in Figures 6(a) and 6(b)).

Further, it is also possible to extract information about relative positional deviation between the mold and the substrate without extracting the components of basic frequency of the periodic structures from the image information obtained by the image pickup device, i.e., by inputting the basic frequencies themselves as preliminarily determined information. The multiplication in Step S-3 is performed by using two sine functions but may also be performed by utilizing cosine functions or other functions.

Hereinbelow, the case where the alignment method of this embodiment is applied to an imprint apparatus will be described with reference to Figures 7 to 11.

5 Figure 7 is a schematic view for illustrating the imprint apparatus.

The imprint apparatus includes a light source 7000 (halogen lamp), an image pickup device 7010 (CCD: 1.3 megapixels; 12 bit), a lens 7020 (magnification: 10 10; numerical aperture (NA): 0.28), and an ultraviolet (UV) light source 7030 for during a photocurable resin material. The UV light source is inclined with respect to an optical axis of the lens 7020.

The imprint apparatus further includes a 15 housing 7040 for holding a mold, a mold 7060 provided with an imprint pattern, a wafer substrate 7070 formed of silicon or the like, a vibration isolation table 7080, and a group of stages 7081, 7082, and 7083 which are operable in a perpendicular direction, a lateral 20 direction, and a longitudinal direction, respectively, in order to effect course adjustment. These stages have alignment accuracies of ±1 μm or less with respect to XYZ directions and an accuracy of ±1 m degree or less with respect to θ (a rotation angle 25 about an axis). The imprint apparatus further includes a fine adjustment stage 7084 utilizing a piezoelectric element.

In the imprint apparatus, it is possible to effect alignment adjustment with an accuracy of 1 nm or less in a range of 200 μm in each of XYZ directions. Further, ranges with respect to α (a rotation axis about x-axis) and β (a rotation axis about y-axis) are ±1000 μrad or less, and a range of θ is ±800 μrad.

The imprint apparatus further includes a computer 7050 for performing signal processing and sending control signals.

The mold 7060 is formed of quartz and provided in advance with a rectangular or cross alignment mark and a grating with pitch P_1. The mold has a 50 nm-thick surface layer of SiN. The alignment mark has grooves having a depth of 166 nm. The substrate 7070 formed of silicon wafer is provided with an alignment mark and a grating with pitch P_2. The alignment mark for the substrate has grooves having a depth of 150 nm.

Figure 8 shows a state in which a mold-side alignment mark 8000 (enclosed by a solid line) and a substrate-side alignment mark 8500 (enclosed by dotted line) observed through an image pickup device overlap each other. As described above, in Figure 8, the mold is also provided with the grating with pitch P_2. Further, the substrate is also provided with the grating with pitch P_1. The gratings with pitches P_1 and P_2 provided each of the substrate and the mold are disposed so as not to optically overlap each other.

Further, at mutually nonoverlapping positions, a first area (region) 8010 and a second area (region) 8510 are determined. In Figure 8, a resist as the photocurable resin is interposed between the mold and the substrate.

5 Figure 9(a) shows the first area 8010 extracted from the image data in Figure 8, and Figure 9(b) shows the second area 8050 extracted from the image data in Figure 8.

With reference to Figure 10, signal processing 10 will be specifically described.

First, image data are selected and extracted from the first and second areas (steps 2910 and 2920 in Figure 10).

On the basis of these image data, basic 15 frequency components of periodic structures are extracted as sine waves with an FFT (fast Fourier transform) filter after magnification correction and conversion of two-dimensional data into one-dimensional data are made as desired (steps 2915 20 and 2925). These sine waves are mathematically multiplied as described above (step 2930). Incidentally, in the above described equation, the positional deviation δ is represented by an equation attributable to the positions on the substrate side. 25 In other words, the equation is used for performing the signal processing on the presumption that the mold-side positions are located at desired positions.

The computation may also be performed on the presumption that the substrate-side positions are located at desired positions. It is also possible to perform the computation using both of positional deviations d1 and d2 attributable to the positions on the mold side and the substrate side, respectively.

By the computation (step 2930), it is possible to obtain a component of moire fringes represented by the following term (step 2940).

$$\cos\{2\pi(\frac{1}{P_1}-\frac{1}{P_2})x-\frac{2\pi}{P_2}\delta\}$$

From this term, a phase component $(-(2\pi/P_2)\delta)$ is extracted.

Figure 11 shows profiles of the moire fringe component, wherein a dotted line 3000 represents the case where there is no out-of-phase component, and a solid line 3010 represents the case where the moire fringe component is actually deviated by the above-described phase component 3500.

It is possible to effect positional adjustment (alignment) by moving the substrate relative to the mold so as to cancel the phase component deviation.

Incidentally, in the case where the substrate and the mold are deviated from desired positions by a degree equal to or more than the period of the moire fringes, a magnitude of actual phase deviation cannot be accurately determined in some cases. In these cases,

it is preferable that course adjustment with the cross or rectangular mark provided close to the grating is initially performed and thereafter fine adjustment with the grating is performed to detect the above described magnitude of the phase deviation. The fine adjustment is not necessarily performed by using the alignment mark shown in Figure 8 but may also be performed by appropriately employing a known method.

(Fourth Embodiment)

An imprint method according to this embodiment relates to an imprint method in which a pattern formed on a processing surface of the mold is transferred by curing a resin material disposed on the surface of the substrate.

The imprint method is characterized in that when an alignment mark provided to the mold is observed through the image pickup device, a wavelength of light entering the image pickup device is controlled depending on the gap between the mold and the substrate or a thickness of a member constituting the alignment mark. More specifically, in the imprint method, the resin material onto which the pattern is to be transferred is interposed between the mold and the substrate. In the case where refractive indices of the resin material and the mold are close to each other, a phenomenon which is called index matching such that the alignment mark including projections and

recesses formed on the mold disappears is caused to occur. In an actual observation, it is difficult to perform the observation of the alignment mark for the mold.

5 In order to obviate the index matching by which the mold mark disappears, it is effective to use a mark formed of a high-refractive index material.

However, in the imprint method, the gap between the mold and the substrate can be several tens 10 of nanometers to several hundreds of nanometers. In such a case, the contrast of the mark can be lowered by an interference effect of light, thus being required to be further improved.

The reason why the use of the high-refractive 15 index material for the mold for imprint (particularly at the alignment mark portion) is preferable will be described.

Assuming that the mold mark is constituted by SiO_2 having refractive index of 1.45, a resin 20 materials having a refractive index of 1.5, and SiN having a refractive index of 2.0, a reflectance R at an interface between materials having refractive indices n_1 and n_2 is represented by the following equation.

25 $$R = \left(\frac{n_1 - n_2}{n_1 + n_2} \right)^2$$

Accordingly, a reflectance R at an interface

between SiO_2 and the resin material is:

$R = 2.9 \times 10^{-4}$.

This value is very small. When the mark is observed, the mark is less observable due to the above
5 described index matching.

On the other hand, a reflectance R at an interface between SiN and the resin material is:

$R = 2.0 \times 10^{-2}$.

This value is larger than that at the
10 interface between SiO_2 and the resin material by about two digits. Here, a reflectance R at an interface between SiO_2 and air is:

$R = 3.4 \times 10^{-2}$.

As described above, it is found that the
15 reflectance is largely improved by using SiN as the material for the mold mark.

Incidentally, in the imprint method, the gap between the mold and the substrate and the thickness of the film of the high-refractive index material can
20 be several tens of nanometers to several hundreds of nanometers. In such a case, the light interference effect is remarkably obtained.

Figure 19 is a graph showing a relationship between a wavelength and a reflected light intensity
25 in the case where the mold mark has a four-layer structure including layers of SiO_2, SiN, a resin material (thickness (gap): 100 nm), and Si, and a

thickness of SiN layer is variable. More specifically, Figure 12 shows a result of simulation with the four-layer structure including an Si layer having an infinite thickness, a 100 nm-thick resin material
5 layer formed on the Si layer, an SiN layer (thickness: 20 nm, 50 nm, 150 nm) formed on the resin material layer, and an SiO_2 layer which has an infinite thickness and is disposed on the SiN layer.

Calculation of values is made by using a model
10 for Fresnel reflection. As a reference, a three-layer structure including three layers (SiO_2 layer/resin material layer/Si layer) prepared by omitting the SiN layer from the above descried four-layer structure is employed.

15 A resultant contrast when the mark is observed is better with a larger difference between the four-layer structure including the SiN layer and the three-layer (reference) structure lacking the SiN layer.

20 For example, at the wavelength of 600 nm, a reflected light intensity is 0.27 when the SiN layer has a thickness of 50 nm and is 0.11 when the SiN layer has a thickness of 150 nm. The reference structure provides a reflected light intensity of 0.11
25 at the wavelengths of 400 - 800 nm, so that a contrast at the wavelength of 600 nm is increased in the order of the SiN layer thicknesses of 150 nm, 20 nm, and 50

nm. At the wavelength of 800 nm, a contrast is increased in the order of 20 nm, 50 nm, and 150 nm (SiN layer thickness). Further, at the wavelength of 400 nm, a contrast is highest at the SiN layer
5 thickness of 20 nm.

Figure 20 is a graph showing a relationship between a wavelength and a reflected light intensity in the case where the mold mark has a four-layer structure including layers of SiO_2, SiN (thickness: 50
10 nm), a resin material, and Si, and a thickness of the resin material layer as a gap layer is variable. More specifically, values of the thickness (gap) are 50 nm, 100 nm, and 200 nm.

When the reflected light intensities at the
15 wavelength of 600 nm are compared, the intensity values are 0.273 for the gap (resin material layer thickness) of 100 nm, 0.099 for the gap of 50 nm, and 0.033 for the gap of 200 nm. Since the intensity of the reference structure is 0.11 at the wavelengths of
20 400 - 800 nm (Figure 19), a contrast at the wavelength of 600 nm is increased in the order of the gaps of 50 nm, 200 nm, and 100 nm. A contrast at the wavelength of 500 nm is increased in the order of the gaps of 200 nm, 50 nm, and 100 nm. Further, a contrast at the
25 wavelength of 800 nm is increased in the order of the gaps of 100 nm, 50 nm and 200 nm.

As described above, the reflectance is changed

depending on the wavelength in the case where the SiN layer thickness or the gap (resin material layer thickness) is several tens of nanometers to several hundreds of nanometers (a fraction of the wavelength of light for observation to several times the wavelength of light for observation). For this reason, it is desirable that the wavelength of light entering the image pickup device is controlled depending on the SiN layer thickness or the gap.

Incidentally, when spectra of light entering the image pickup device are in a range of 400 - 800 nm, a contrast is determined by a difference between an average of the spectra in this range and the reference(intensity:0.11).

Next, an alignment method will be described.

In the alignment, accuracy of alignment is improved with an increase in contrast of the mold mark. An observation wavelength of the mark in the case where alignment is effected while bringing the mold and the substrate near to each other will be described. The SiN layer has a thickness of 50 nm in this case. When the gap is 200 nm, the mark is observed at the wavelength of 400 - 450 nm. When the gap is 100 nm in a further approximated state, the mark is observed at the wavelength of 500 - 550 nm. When the gap is 50 nm in a still further approximated state, the mark is observed at the wavelength of 400 - 450 nm. Even when

the gap is another value, the mark is observed at an optimum wavelength.

A method of selecting the wavelength may be a method using a color filter or a method using a
5 plurality of laser beams. The color filter may be disposed on the illumination optical system side or the image pickup device side.

In a preferred embodiment of the present invention, the above described constitutions of this
10 embodiment are incorporated into those described in First to Third Embodiments.

For example, in the above described First to Third Embodiments, in the case where optical information is inputted into the image pickup device
15 through a wavelength filter, it is possible to always obtain information about an image having a high contrast by changing a transmission wavelength range of the wavelength filter depending on the gap. Further, in an imprint apparatus for transferring a pattern
20 formed on a processing surface of a mold by curing a resin material in a substrate surface, it is preferable that the apparatus includes an image pickup device for observing the mold and a means for controlling a wavelength of light entering the image
25 pickup device depending on a gap between the mold and the substrate. The means for controlling the wavelength is constituted by the color filter or a

plurality of light sources (capable of outputting light fluxes at a plurality of wavelengths).

(Other Embodiments)

In the present invention, it is possible to employ the following constitutions.

More specifically, it is possible to employ a constitution in which an optical system for observing a first object position at a processing surface of the mold and a second object position at a portion closer, than the processing surface, to a member to be processed is used and alignment between the mold and the member to be processed is effected by using a means for recognizing a relative relationship of (or a difference in) observation position between a first image pickup device for observing the first object position and a second image pickup device for observing the third object position. In this case, it is possible to employ a constitution in which the reference substrate is used as the means for recognizing the difference in observation position. Further, it is possible to employ a constitution in which the alignment between the mold and the member to be processed is effected by comparing data obtained in advance by the first and second image pickup devices with data (currently) obtained by the first and second image pickup devices. Further, it is also possible to employ a constitution in which the alignment between

the mold and the member to be processed is effected by making comparison in each of several areas in image pickup areas of the first and second image pickup devices.

5 Further, in order to realize a processing method by the above described pattern transfer, it is possible to employ the following constitutions.

In the processing method, an optical system for observing a first object position at a processing
10 surface of the mold and a second object position at a portion closer to the member to be processed with respect to the processing surface of the mold is used. The processing method can be constituted so that alignment between the mold and the member to be
15 processed is effected by using a means for recognizing a relative relationship of (or a difference in) observation position between a first image pickup device for observing the first object position and a second image pickup device for observing the second
20 object position. In this case, it is possible to employ a constitution in which the reference substrate is used as the means for recognizing the difference in observation position. Further, it is possible to employ a constitution in which the processing method
25 includes a step of recognizing the difference in observation position by the reference substrate and a step of effecting the alignment between the member to

be processed and the mold at the second object position. Further, it is possible to employ a constitution in which the alignment between the mold and the member to be processed is effected by comparing data obtained in advance by the first and second image pickup devices with data (currently) obtained by the first and second image pickup devices. Further, it is possible to employ a constitution in which the processing method includes a step of selecting a plurality of areas from an image obtained by the first image pickup device, a step of effecting first signal processing in each of the plurality of areas, and a step of effecting second signal processing on the basis of a result of the first signal processing. Further, it is possible to employ a constitution in which the data obtained by the first and second image pickup devices by using grating having different pitches as marks for the alignment described above are overlaid or superposed and subjected to signal processing to generate moire fringes and the generated moire fringes are utilized.

In the above described embodiments of the present invention, a relative positional relationship between the respective image pickup ranges at two (first and second) object positions is measured or determined with the reference substrate by using the optical system for observing coaxially the two object

positions of the mold and the substrate. By utilizing a result of measurement, it is possible to effect the alignment between the mold and the substrate. As a result, the alignment can be effected in a separation state between the mold and the substrate, so that it is possible to effect the alignment between the mold and the substrate without image to the mold and the substrate. Further, by disposing the marks for the mold and the substrate in different areas as seen in a normal direction, interference between the marks for the mold and the substrate does not occur. As a result, the signal processing becomes easy.

Further, the pattern transfer apparatus according to the present invention can also be constituted as described below. Herein, the apparatus means a pattern transfer apparatus for transferring the imprinting pattern formed on the mold onto the substrate or the resin material interposed between the substrate and the mold. The pattern transfer apparatus includes a first image pickup portion for obtaining an image at a first depth of focus and a second image pickup portion for obtaining an image at a second depth of focus. A first alignment mark provided to the mold and a second alignment mold provided to the substrate are disposed within the first depth of focus and observed through the first image pickup portion to obtain a first image. Further, a third mark provided

to the mold or the substrate is disposed within the second depth of focus and observed through the second image pickup portion to obtain a second image. The pattern transfer apparatus is constituted so as to obtain information about a difference in observation range between the first and second image pickup portions by using the first and second images. The third alignment mark may be identical to or different from the first alignment mark or the second alignment mark.

Further, it is also possible to effect the alignment between the mark and the substrate (onto which the imprinting pattern is to be transferred) in an in-plane direction in a state in which the alignment mark for the mold is disposed within the first depth of focus and the alignment mark for the substrate is disposed within the second depth of focus. It is further possible to effect the alignment between the mold and the substrate in the in-plane direction in a state in which the alignment mark for the mold is disposed within the second depth of focus and the alignment mark for the substrate is disposed within the first depth of focus.

(Reference Embodiments)

Hereinbelow, several reference embodiments applicable to the present invention will be described with reference to the drawings.

(Reference Embodiment 1)

In Reference Embodiment 1, an alignment method of the mold and the substrate in the present invention will be described.

5 Figures 12(a) to 12(d) are schematic views for illustrating the alignment method, in this reference embodiment, of the mold and the substrate in which the reference substrate is used.

Referring to Figures 12(a) to 12(d), a 10 reference numeral 101 represents a first object position, a reference numeral 102 represents a second object position, a reference numeral 103 represents a mold, and a reference numeral 104 represents a mold mark. Further, a reference numeral 110 represents a 15 reference substrate, a reference numeral 111 represents a reference substrate mark, a reference numeral 112 represents a substrate, and a reference numeral 113 represents a substrate mark.

In the alignment method of this reference 20 embodiment, an optical system for observing the first object position 101 at a processing surface of the mold 103 and the second object position 102 located in the substrate 112 side with respect to the processing surface is used. By the optical system, the mold mark 25 104 and the substrate mark 113 are observable at the same time.

The first object position and the second

object position are spaced, e.g., several nanometers or more apart, so that the mold and the substrate are in a noncontact positional relationship even when the substrate is moved at high speed in an in-plane direction parallel to the processing surface.

In each of Figures 12(a) to 12(d), a central view shows a first observation range 106 at the first object position 101. Further, a right-hand view shows a second observation range 107 at the third object position 102. The first observation range 106 includes a first image pickup range 108 as a portion for image pickup, and the second observation range 107 includes a second image pickup range 109 as a portion for image pickup. Further, a left-hand view shows a cross section, of the mold 103 and the reference substrate 110 or the substrate 112, taken along a vertical bisecting line, such as A-A' line indicated in the central view of Figure 12(a).

Generally, it is not easy to dispose coaxially the image pickup device for observing these two (first and second) object positions with an accuracy on the order of nanometers, so that a difference in center position between the first observation range and the second observation range is caused to occur. Further, a difference in center position between each observation range and an associated image pickup range is also caused to occur. In addition, there is a

difference in center position between the first observation range and the mold mark. Objects to be finally aligned with each other are the mold and the substrate, so that the center of the substrate mark is aligned with the center of the mold mark in this reference embodiment. For simplicity of explanation, it is assumed that the first observation range and the first image pickup range coincide with each other and the second observation range and the second image pickup range coincide with each other. Even when this assumption is made, generality of explanation is not lost. Further, for simplicity of explanation, it is assumed that the center positions of the first observation range and the second observation range are deviated only in y-direction. A direction from the second object position toward the first object position is taken as a positive direction of z-direction.

The alignment method of this reference embodiment will be briefly described. In the alignment method, the reference substrate 110 is used for the alignment between the mold and the substrate.

A procedure of the alignment method is as follows.

(1) The mold and the reference substrate are aligned at the first object position by using an in-plane moving mechanism (Figure 12(a)).

(2) The reference substrate is moved in a negative direction of z-direction and an image thereof is constituted and obtained at the second object position (Figure 12(b)).

5 (3) At the second object position, the observed image and the substrate are aligned by using the in-plane moving mechanism (Figure 12(c)).

(4) Only by moving the substrate in the positive direction of z-direction, the substrate is aligned

10 with the mold at the first object position (Figure 12(d)).

In such a step-and repeat method that a predetermined pattern is repetitively transferred at many points on the same substrate, alignment may be

15 effected only at a first point on the substrate. Thereafter, it is possible to effect repetitive transfer with an accuracy of the in-plane moving mechanism (on the order of subnanometers).

Next, a detailed description will be made.

20 In order to align the substrate mark with a desired position at the first object position, it is necessary to determine a position, at which the substrate mark should be disposed at the second object position, corresponding to the desired position at the

25 first object position. This operation is, e.g., performed only during replacement of the mold. Figure 12(a) shows a state in which the reference substrate

mark 111 is caused to correspond to the mold mark at the first object position 101. This state is realized in the following manner. On the assumption that the mold mark 104 is located at the center of the first image pickup range, the substrate is disposed at a substrate holding portion and the center of the reference substrate mark 111 can be caused to correspond to (the center of) the mold mark 104 by using the in-plane moving mechanism. The alignment (positional adjustment) at this time can be effected with an accuracy on the order of nanometers by using the in-plane moving mechanism. During the alignment, the image at the second object position 102 is not particularly required to be used.

Next, as shown in Figure 12(b), the reference substrate is moved in the negative direction of z-direction by using a substrate hoisting and lowering mechanism so that the reference substrate mark 111 reaches the second object position 102. During this movement, the reference substrate is not deviated in xy-directions. In the resultant state, the reference substrate mark 111 is observed at the second object position 102 and an image in this state is picked up and stored. At this time, the image at the first object position 101 is not particularly required to be used.

Next, with reference to Figures 12(c) and

12(d), the method of the alignment between the mold and the substrate will be described. This operation is performed every disposition (or placement) of a fresh substrate.

5 As shown in Figure 12(c), the substrate holding portion holding the substrate 112 is disposed at a designated position (referred to as "F1-1") opposite to the mold 103 by the in-plane moving mechanism. At this time, the substrate mark 113 is

10 observed at the second object position 102. Then, alignment is effected so that the center of the substrate mark 113 is aligned with the center of the reference substrate mark 111 observed at the second object position 102 shown in Figure 12(b) by using the

15 in-plane moving mechanism. This alignment can be effected at high speed since the mold and the substrate are placed in a separation state. A difference (referred to as "E1-1") between the designated position (F1-1) of the substrate holding

20 portion at this time and a designated position of the substrate holding portion after completion of the alignment (referred to as "S1-1") is stored. In this case, it is not particularly necessary to use the image at the first object position 101.

25 Next, as shown in Figure 12(d), the substrate 112 is raised in the positive direction of z-direction, so that the substrate 112 is disposed at the first

object position 101. At this time, the mold and the substrate is basically placed in a completion state of alignment. Thereafter, imprint is effected by setting a designated position on the presumption that there is
5 the difference (deviation) (E1-1) with respect to subsequent transfer onto the same substrate. In this case, it is not particularly necessary to use the image at the second object position 102.

In the case where the mold and the substrate
10 are deviated from each other and located outside a tolerable range, it is also possible to effect further alignment between the mold and the substrate. This operation may be required, e.g., in the case where the positions of the mold and the substrate are deviated
15 from each other due to a stress, exerted thereon, caused by the contact between the mold and the substrate via the resin material. In the case where the positional deviation between the mold and the substrate occurs, when an amount of the deviation
20 between the mold and the substrate is identical irrespective of the position of the substrate, the following processing is performed. More specifically, a difference (referred to as "E1-2") between the designated position (F1-1) of the substrate holding
25 portion at that time and a position of the substrate holding portion at the time of completion of the alignment (referred to as "S1-2") is stored. In this

case, the alignment has already been effected at the second object position as shown in Figure 1(c), so that a value of the difference (E1-2) is not large. Thereafter, imprint is effected by setting a designated position on the presumption that there is the difference (deviation) (E1-2) with respect to subsequent transfer onto the same substrate.

The above described alignment is effected on the entire surface of the substrate on the basis of information about the positional deviation between the mold and the substrate at a certain point of the substrate. However, it is also possible to effect the alignment between the mold and the substrate on the basis of information about positional deviation, at the entire surface of the substrate, obtained in advance of the alignment.

Next, a constitution of the reference substrate used in this reference embodiment will be described with reference to Figures 13(a) to 13(c) showing the constitution of the reference substrate.

As the reference substrate, it is also possible to use the substrate itself onto which the imprinting pattern is to be transferred. However, in this case, there is apprehension that distortion of the substrate during the process and a difference among individual substrates can occur. For this reason, it is desirable that a stable reference substrate is

used.

A reference substrate 201 shown in Figure 13(a) has a square shape and is constituted so that an area 202 having a size equal to a pattern area of the mold is disposed on the reference substrate 201 and four reference substrate marks 203 are disposed at four corners of the area 202.

A reference substrate 204 shown in Figure 13(b) has a circular shape and is constitute so as to have a size equal to that of the substrate onto which the imprinting pattern is to be transferred. On the reference substrate 204, there are a pattern are 205 in which reference substrate marks are provided and a pattern area 206 in which no reference substrate mark is provided. In this constitution, correction of the positional deviation can be made at several positions at which the reference substrate mark is provided.

A reference substrate 207 shown in Figure 13(c) is constituted by the substrate itself onto which the imprinting pattern is to be transferred. In this case, the correction may be made at all of positions in pattern areas or at the several positions shown in Figure 13(b).

Next, an optical system for measurement used in this reference embodiment will be described with reference to Figure 14 showing a constitute of the optical system.

In the optical system in this reference embodiment, light emitted from a light source 301 passes through an illumination optical system 302, a first beam splitter 303, a first imaging optical system 304 to reach a mold 309 and a substrate 312. Light reflected by the mold 300 and the substrate 312 passes through the first imaging optical system 304, the first beam splitter 303, a second imaging optical system 306, and a second beam splitter 305 to form an image on a first image pickup device 307 and a second image pickup device 308. In this reference embodiment, a mold mark 310 is formed as an image on the first image pickup device 307 and a second mark 311 is formed as an image on the second image pickup device 308. An image of the first object position 313 is formed on the first image pickup device 307 and an image of the second object position 314 is formed on the second image pickup device 308.

Next, a processing apparatus, used in this reference embodiment, constituting a pattern transfer apparatus for transferring an imprinting pattern formed on a mold onto a substrate or a resin material interposed between the substrate and the mold will be described with reference to Figure 15 showing an example of a constitution of the processing apparatus in Reference Embodiment 1.

Referring to Figure 15, the processing

apparatus includes an exposure light source 401, a body tube 402, a mold holding portion 403, a substrate holding portion 404, a substrate hoisting and lowering mechanism (z-direction) 405, an in-plane moving mechanism (xy-directions) 406, the optical system for measurement shown in Figure 14, image pickup devices 408, and an analyzing mechanism 409.

The mold holding portion 403 effects chucking of a mold 411 according to a vacuum chucking method or the like. A substrate 412 is movable to a desired position by the in-plane moving mechanism 406. Further, by the substrate hoisting and lowering mechanism 405, adjustment of a height of the substrate 412 and application of pressure can be effected. The in-plane moving mechanism 406 and the substrate hoisting and lowering mechanism 405 are subjected to measurement of distance by an interferometer or the like with a control accuracy on the order of subnanometers. Control of positional movement of the substrate, pressure application, exposure and the like is made by an imprint control mechanism 410.

(Reference Embodiment 2)

In Reference Embodiment 2, a method of alignment between the mold and the substrate different from the alignment method of Reference Embodiment 1 will be described.

In this reference embodiment, explanation of

the alignment method common to Figures 12(a) to 12(d) is omitted and only a different constitution thereof will be described.

Figures 16(a) to 16(c) include schematic views
5 for illustrating a mold of alignment between a mold 502 and a substrate 513.

In this reference embodiment, at both surfaces of a reference substrate 505, a first reference substrate mark 506 and a second reference substrate
10 mark 504 are disposed, respectively. Further, an optical thickness of the reference substrate 505 is made equal to a distance between a first object position 501 and a second object position 503. Based on these features, it is possible to determine a
15 position, to which a substrate mark should be moved at a second object position in order to align the substrate mark with a desired position of a mold mark at a first object position, at one time as described below.

20 Figure 16(a) includes schematic views showing the case where the first reference substrate mark 506 of the reference substrate 505 is located at a first object position 501. Further, the second reference substrate mark 504 is located at a second object
25 position 503. The first reference substrate mark 506 is disposed in a first image pickup area 510 provided in a first observation area 509. Further, the second

reference substrate mark 504 is disposed in a second pickup area 512 provided in a second observation area 511. A reference numeral 508 represents a difference between center positions in the first and second image pickup ranges 510 and 512.

First, the reference substrate 505 is disposed on a substrate holding portion (not shown) and on the basis of a mold mark 507, alignment (positional adjustment) of the first reference substrate mark 506 is effected at the first object position 501 by an in-plane moving mechanism. More specifically, e.g., the alignment is effected so that the center of the first reference substrate mark 507 and the center of the mold mark 506 coincide with each other. At this time, at the second object position 503, the second reference substrate mark 504 is located and an image thereof is stored.

Thereafter, the reference substrate 505 is removed from the substrate holding portion.

Next, a method of alignment of the substrate will be described. This method is basically identical to that in Reference Embodiment 1.

More specifically, as shown in Figure 16(b), the substrate holding portion holding the substrate is disposed at a designated position (referred to as "F2-1") opposite to the mold by the in-plane moving mechanism. At this time, a first substrate mark 514

and a second substrate mark 515 are observed at the second object position. Then, alignment is effected so that the center of the first substrate mark 514 is aligned with the center of the reference substrate mark 504 observed at the second object position 503 shown in Figure 16(a) by using the in-plane moving mechanism. A difference (referred to as "E2-1") between the designated position (F2-1) of the substrate holding portion at this time and a designated position of the substrate holding portion after completion of the alignment (referred to as "S2-1") is stored.

Figure 16(c) shows a state in which the substrate holding portion holding the substrate is raised, so that the first and second substrate marks 514 and 515 are disposed at the first object position 501. In this state, alignment between the mold and the substrate is ordinarily completed. Thereafter, imprint is effected by setting a designated position on the presumption that there is the difference (deviation) (E2-1) with respect to subsequent transfer onto the same substrate.

In the case where the mold and the substrate are deviated from each other and located outside a tolerable range, similarly as in Reference Embodiment 1, the second substrate mark 515 is positionally aligned on the basis of the mold mark 507 at the first

object position 501 shown in Figure 16(c) by using the in-plane moving mechanism. In this case, the alignment at the second object position 503 shown in Figure 16(b) has already been effected, so that a degree of the positional deviation is not large. A difference (referred to as "E2-2") between the designated position (F2-1) of the substrate holding portion and a position of the substrate holding portion at the time of completion of the alignment (referred to as "S2-2") is stored. Thereafter, imprint is effected by setting a designated position on the presumption that there is the difference (deviation) (E2-2) with respect to subsequent transfer onto the same substrate.

(Reference Embodiment 3)

In Reference Embodiment 3, a method of alignment between the mold and the substrate different in image processing method from the alignment method of Reference Embodiment 1 will be described.

In this reference embodiment, explanation of the alignment method common to Figures 12(a) to 12(d) is omitted and only a different constitution thereof will be described.

Figures 17(a) to 17(c) include schematic views for illustrating an image processing method in this reference embodiment.

First, the case where a reference substrate 613 is observed at a first object position 601 will be

described. Figure 17(a) shows a state in which a reference substrate mark 614 of the reference substrate 613 is located at the first object position 601. In this reference embodiment, in a first image pickup area 608 in a first image pickup range 605, a first area A 610 is designated as an area including a mold mark 604 of a mold 602 on the basis of the mold mark 604. Thereafter, a first area B 611 and a first area C 613 are designated with a certain distance (interval) between adjacent areas. The reference substrate mark 614 is positionally adjusted with respect to the first area C 613 by being moved by an in-plane moving mechanism. At this time, e.g., the first area C is disposed at a desired position by effecting signal processing such that the first area A 610 and the first area C 612 are selected or extracted from an image, subjected to contrast adjustment for each extracted image, and the two extracted images are superposed. After the alignment between the reference substrate mark 604 and the first area C 612 is completed, the reference substrate 613 is lowered by a substrate hoisting and lowering mechanism to a second object position 603 at which the reference substrate mark 604 is observed. A reference numeral 606 represents a difference between center positions in first and second image pickup ranges 608 and 609. Figure 17(b) shows a state in which the reference

substrate mark 604 of the reference substrate 613 is located at the second object position 603. In this state, in a second image pickup area 609 in a second image pickup range 607, a second area C 617 is designated on the basis of the reference substrate mark 604 so as to include the reference substrate mark 604. Thereafter, a second area B 616 and a second area A 615 are designated with a certain distance (interval) between adjacent areas. Thereafter, the reference substrate 505 is removed from the substrate holding portion.

Next, a method of alignment of the substrate will be described. Figure 17(c) includes views for illustrating the case where a substrate 618 is observed at the second object position 603.

More specifically, as shown in Figure 17(c), the substrate holding portion holding the substrate is disposed at a designated position (referred to as "F3-1") opposite to the mold by the in-plane moving mechanism. At this time, a substrate mark 619 is observed at the second object position. In this state, the second area B 616 is selected or extracted from an image and superposed on an image of the second area C 617 obtained in the operation described with reference to Figure 17(b) to effect positional adjustment. This positional adjustment can be performed at high speed since the contact between the mold and the substrate

is not generated at this time. Incidentally, the respective images are subjected to signal processing such as contrast adjustment or the like in advance.

Next, the case where the substrate 618 is observed at the first object position 601 will be described.

Figure 17(d) shows a state in which the substrate 618 is raised in the positive direction of z-direction by the hoisting and lowering mechanism to dispose the substrate mark 619 at the first object position 601. In this state, the alignment between the mold 602 and the substrate 618 is ordinarily completed, so that a resultant positional deviation is expected to be a level within a tolerable range. A difference (referred to as "E3-1") between the designated position (F3-1) of the substrate holding portion at this time and a designated position of the substrate holding portion after completion of the alignment (referred to as "S3-1") is stored. Thereafter, imprint is effected by setting a designated position on the presumption that there is the difference (deviation) (E3-1) with respect to subsequent transfer onto the same substrate.

In the case where the mold and the substrate are deviated from each other and located outside a tolerable range, similarly as in Reference Embodiment 1, the alignment between the mold 602 and the

substrate 618 is finally effected at the first object position 601. In this case, the alignment at the second object position 603 shown in Figure 17(c) has already been effected, so that a degree of the positional deviation is not large. A difference (referred to as "E3-2") between the designated position (F3-1) of the substrate holding portion and a position of the substrate holding portion at the time of completion of the alignment (referred to as "S3-2") is stored. Thereafter, imprint is effected by setting a designated position on the presumption that there is the difference (deviation) (E3-2) with respect to subsequent transfer onto the same substrate.

As described above, an effect of using different areas in the image pickup area of the image pickup device is that reflectances of the mold and the substrate are different from each other and thus the images of the mold and the substrate can be independently subjected to signal processing to facilitate an increase in accuracy of alignment. Further, it is not necessary to consider an influence of mutual interference since the mold and the substrate are not vertically overlaid on each other, so that a degree of freedom of the mark can be increased.

Next, a method of effecting high-accuracy alignment by generating moire fringes in the mark

through image processing will be described.

Figures 18(a) to 18(f) are schematic views for illustrating alignment marks used when alignment is effected by image-processing moire fringes in
5 Reference Embodiment 3.

Figure 18(a) shows a first mark including a bar pattern 701 with a pitch P_1 and a bar pattern 702 with a pitch P_2. Figure 18(b) shows a second mark including the bar pattern 701 with the pitch P_1 and a
10 bar pattern with the pitch P_2, wherein the bar patterns 701 and 702 have an arrangement opposite to that of the bar patterns 701 and 702 in the first mark shown in Figure 18(a). By mutually overlaying the first mark and the second mark, a composite image 706
15 as shown in Figure 18(c) is formed. In this composite image 706, left-hand and right-hand moire fringes are in phase with each other. Figure 18(c) shows a state in which alignment between the mark and the substrate is completed.

20 Incidentally, in a state in which the alignment between the mark and the substrate is not completed, the left-hand and right-hand moire images are out of phase with each other. The moire fringes have a period equal to a pitch P_M represented by the
25 following equation.

$$P_M = \frac{P_1 P_2}{|P_1 - P_2|}$$

As described above, a positional deviation between the mold and the substrate is enlarged without using optical magnification.

5 Then, the moire fringes are arranged to constitute a first mark 709 for XYθ measurement as shown in Figure 18(d), wherein the first mark 709 includes a first area 710, a second area 711, a third area 712, a fourth area 713, a pattern 707 with a 10 pitch P_3, and a pattern 708 with a pitch P_4. Further, the moire fringes are arranged to constitute a second mark 714 for XYθ measurement as shown in Figure 18(e), wherein the second mark 714 includes the first to fourth areas 710 - 713 and the patterns 707 and 708 15 which are arranged opposite to those in Figure 18(d). With respect to the first mark 709 shown in Figure 18(d) and the second mark 714 shown in Figure 18(e), alignment for y-direction and θ can be effected in the first and third areas 710 and 712 and alignment for 20 x-direction and θ can be effected in the second and fourth areas 711 and 713. Figure 18(f) shows a composite image 716 for XYθ measurement including moire fringes 715 for XYθ measurement at the time after the alignment is completed.

25 The above described apparatuses and methods

according to the present invention can be utilized in manufacturing technologies and the like of semiconductors, optical devices such as photonic crystal and the like, and biochips such as μ-TAS and
5 the like.

[INDUSTRIAL APPLICABILITY]

As described hereinabove, according to the present invention, it is possible to provide an
10 alignment method, an imprint method, an alignment apparatus, an imprint apparatus, and a position measurement method, which have solved the above described problems in the conventional alignment method.

15 While the invention has been described with reference to the structures disclosed herein, it is not confined to the details set forth and this application is intended to cover such modifications or changes as may come within the purpose of the
20 improvements or the scope of the following claims.

CLAIMS

1. An alignment method for effecting alignment between two plate-like objects by using a light source and an image pickup device, said alignment method comprising:

disposing a first plate-like object provided with a first alignment mark and a second plate-like object provide with a second alignment mark opposite to each other;

providing a first area and a second area at mutually nonoverlapping positions in an image pickup area for being observed through the image pickup device;

picking up images of the first and second alignment marks by the image pickup device from a direction substantially perpendicular to an in-plane direction of the first and second plate-like objects;

effecting alignment control for aligning positions of the first and second plate-like objects in the in-plane direction with each other by using first information about a deviation of the first alignment mark from a predetermined position in the first area and second information about a deviation of the second alignment mark from a predetermined position in the second area; and

adjusting a gap between the first and second

plate-like objects so that the gap is 3 μm or less by decreasing the gap while effecting the alignment control.

5 2. A method according to Claim 1, wherein each of the images of the first and second alignment marks picked up by the image pickup device is adjusted in contrast.

10 3. A method according to Claim 1, wherein the first and second areas have an identical planar area.

4. A method according to Claim 1, wherein magnification correction of images observed in the first and second areas is made depending on a change in magnification resulting from heights of the first and second plate-like objects.

5. A method according to Claim 1, wherein an image of the first area is picked up at a first amount of light from the light source and an image of the second area is picked up at a second amount of light, different from the first amount of light, from the light source.

25

6. An alignment apparatus for effecting an alignment method according to Claim 1, comprising:

first movable means for moving at least one of the first and second plate-like objects in the in-plane direction; and

second movable means for moving at least one of the first and second plate-like objects in a direction perpendicular to the in-plane direction.

7. An imprint method for effecting alignment between two plate-like objects by using a light source and an image pickup device to imprint an imprint pattern provided to one of the two plate-like objects on the other plate-like object or a pattern forming layer formed on the other plate-like object, said imprint method comprising:

disposing a mold as a first plate-like object provided with a first alignment mark and a substrate as a second plate-like object provide with a second alignment mark opposite to each other;

providing a first area and a second area at mutually nonoverlapping positions in an image pickup area for being observed through the image pickup device;

detecting the first and second alignment marks by the image pickup device from a direction substantially perpendicular to an in-plane direction of the first and second plate-like objects;

effecting alignment control for aligning

positions of the first and second plate-like objects in the in-plane direction with each other by using first information about a deviation of the first alignment mark from a predetermined position in the first area and second information about a deviation of the second alignment mark from a predetermined position in the second area; and

imprinting an imprint pattern provided to the mold as the first plate-like object on the substrate as the second plate-like object or a pattern forming layer formed on the substrate.

8. An imprint apparatus for effecting an alignment method according to Claim 7, comprising:

first movable means for moving at least one of the first and second plate-like objects in the in-plane direction; and

second movable means for moving at least one of the first and second plate-like objects in a direction perpendicular to the in-plane direction.

9. An alignment method for effecting alignment between two plate-like objects by using an image pickup device, said alignment method comprising:

disposing a first plate-like object provided with a first periodic structure with a pitch P1 as an alignment mark and a second plate-like object provide

with a second periodic structure with a pitch P2 as an alignment mark opposite to each other;

providing a first area and a second area at mutually nonoverlapping positions in an image pickup area for being observed through the image pickup device;

picking up images of the first and second periodic structures in the first and second areas, respectively, by the image pickup device from a direction substantially perpendicular to an in-plane direction of the first and second plate-like objects;

effecting alignment between the first and second plate-like objects in the in-plane direction by extracting basic frequencies corresponding to the first and second periodic structures, respectively, from information about the picked up images, performing computation with the basic frequencies to extract a moire fringe component, and using information about a positional deviation of the first and second plate-like objects in the in-plane direction obtained from the moire fringe component.

10. A position measurement method for measuring positions of two objects by using an image pickup device, said position measurement method comprising:

disposing a first object provided with a first periodic structure with a pitch P1 as an alignment

mark and a second object provide with a second periodic structure with a pitch P2 as an alignment mark opposite to each other;

providing a first area and a second area at mutually nonoverlapping positions in an image pickup area for being observed through the image pickup device;

picking up images of the first and second periodic structures in the first and second areas, respectively, by the image pickup device from a direction substantially perpendicular to an in-plane direction of the first and second objects;

effecting position measurement of the first and second objects in the in-plane direction by extracting basic frequencies corresponding to the first and second periodic structures, respectively, from information about the picked up images, and performing computation with the basic frequencies to extract a moire fringe component.

11. An imprint method comprising:

transferring a pattern formed on a processing surface of a mold onto a resin material provided on a surface of a substrate by curing the resin material,

wherein when an alignment mark provided to a mold is observed through an image pickup device, a wavelength of light entering the image pickup device

depending on a gap between the mold and the substrate or a thickness of a member constituting the alignment mark.

5 12. An alignment method for effecting alignment between two members by using an image pickup device, said alignment method comprising:

disposing a first member provided with a first alignment mark and a second member provide with a second alignment mark opposite to each other;

obtaining first image information about the first alignment mark in a first area in an image pickup area for being observed through the image pickup device;

15 obtaining second image information about the second alignment mark in a second area, different from the first area, in the image pickup area to be observed by the image pickup device;

performing computation of the first image information and the second image information; and

effecting alignment between the two members by using the first image information and the second image information.

25 13. A method according to Claim 12, wherein the computation is performed by using the first image information and the second image information which are

obtained at portions at which the first area and the second area do not overlap each other.

14. An alignment method for effecting alignment between two plate-like objects by using an image pickup device, said alignment method comprising:

disposing a first plate-like object provided with a first periodic structure with a pitch P1 as an alignment mark and a second plate-like object provide with a second periodic structure with a pitch P2 as an alignment mark opposite to each other;

providing a first area and a second area at mutually nonoverlapping positions in an image pickup area for being observed through the image pickup device;

picking up images of the first and second periodic structures in the first and second areas, respectively, by the image pickup device from a direction substantially perpendicular to an in-plane direction of the first and second plate-like objects;

obtaining positional information about a relative position between the first and second plate-like objects by performing computation of image information obtained from the images picked up by the image pickup device; and

effecting alignment between the first and second plate-like objects in the in-plane direction by

using the positional information.

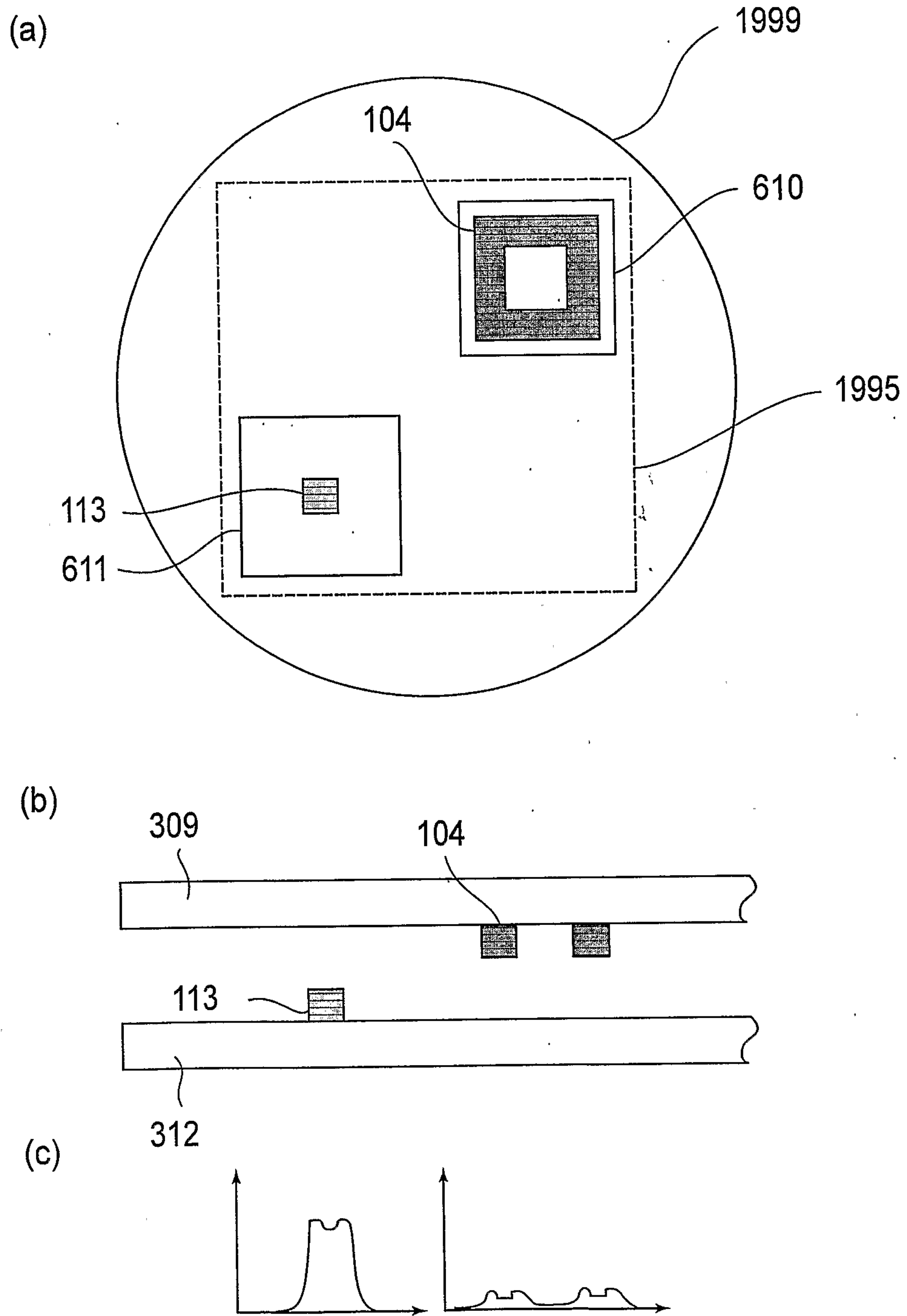


FIG.1

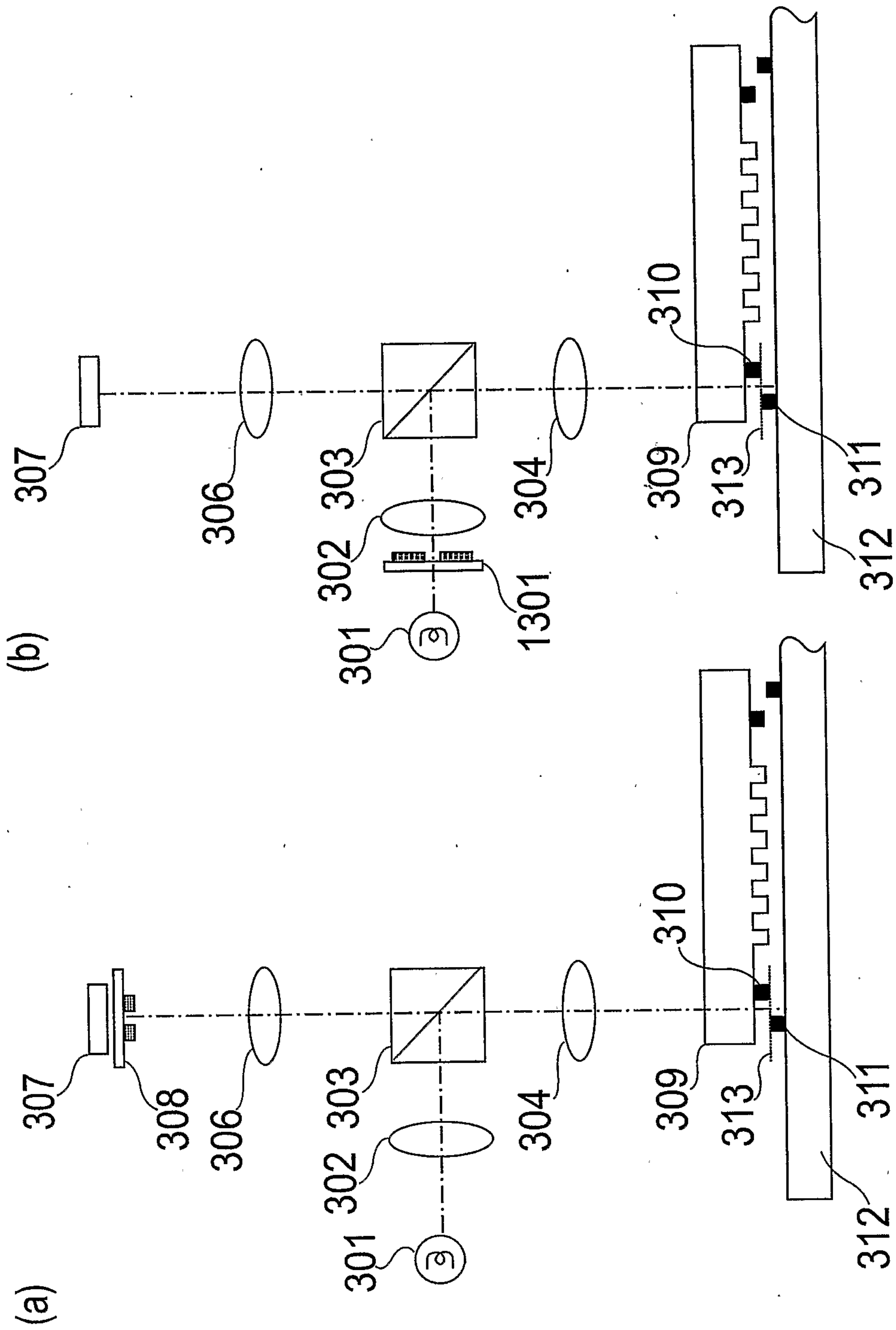


FIG.2

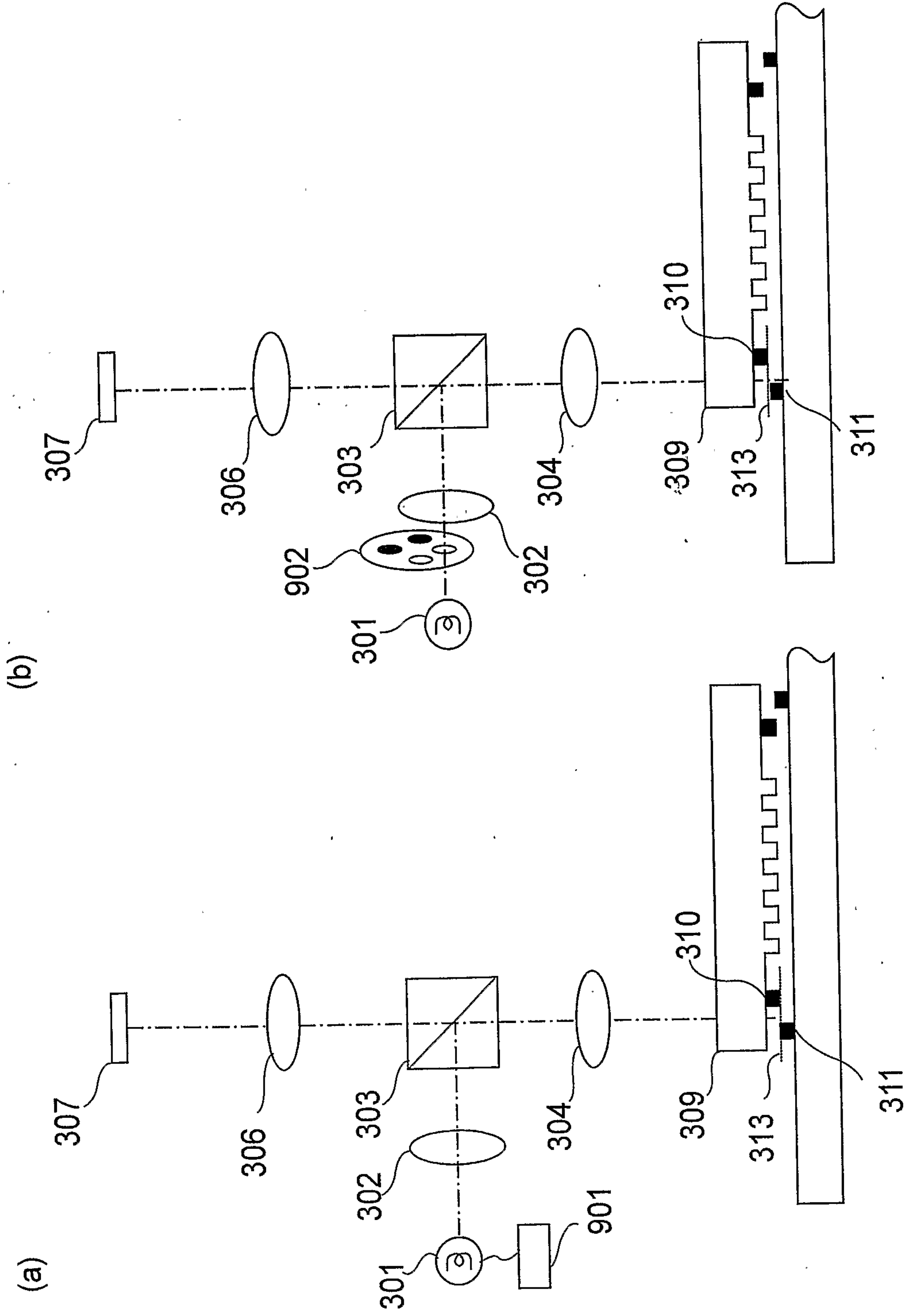


FIG.3

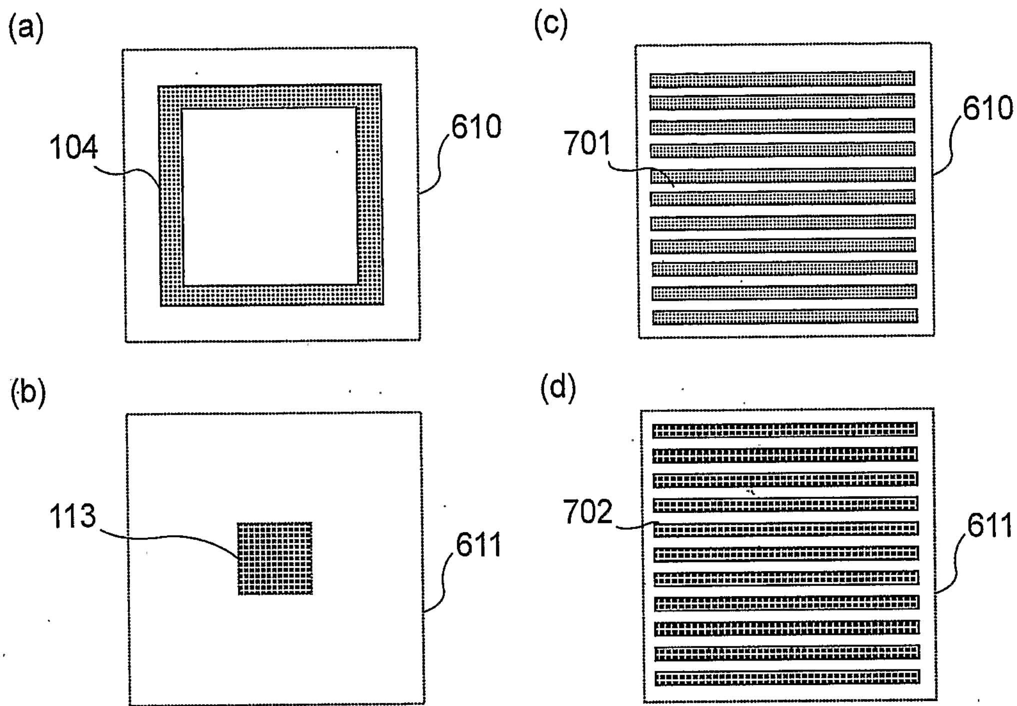


FIG.4

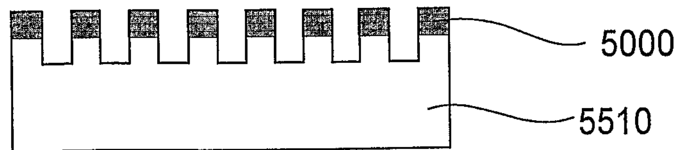
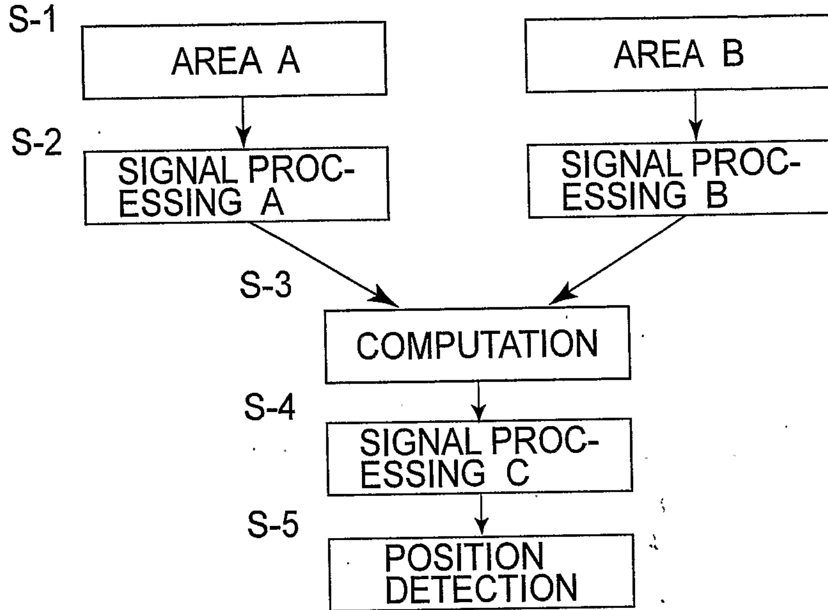


FIG.5

(a)



(b)

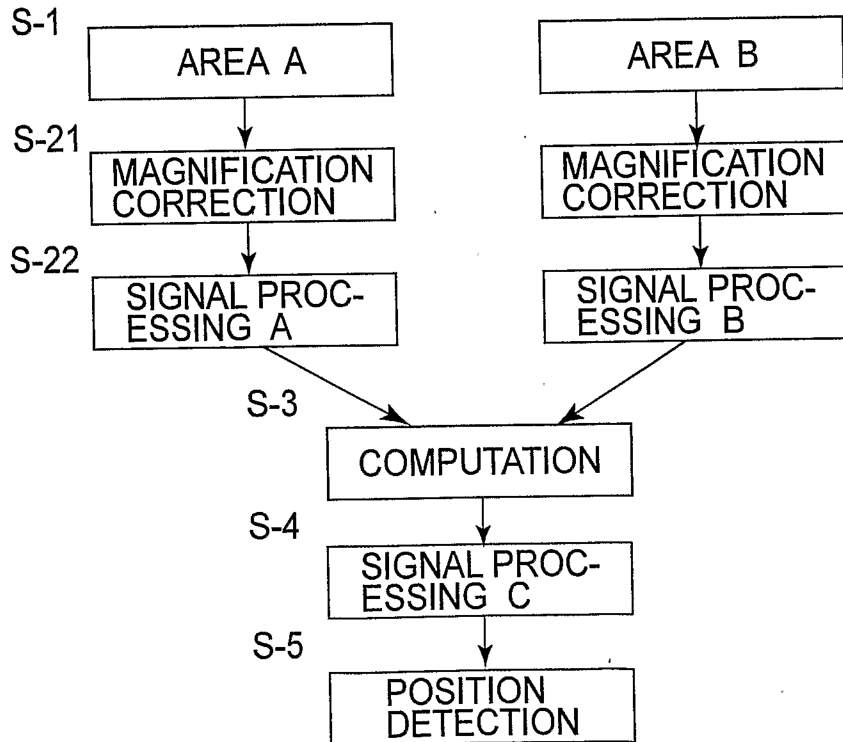


FIG.6

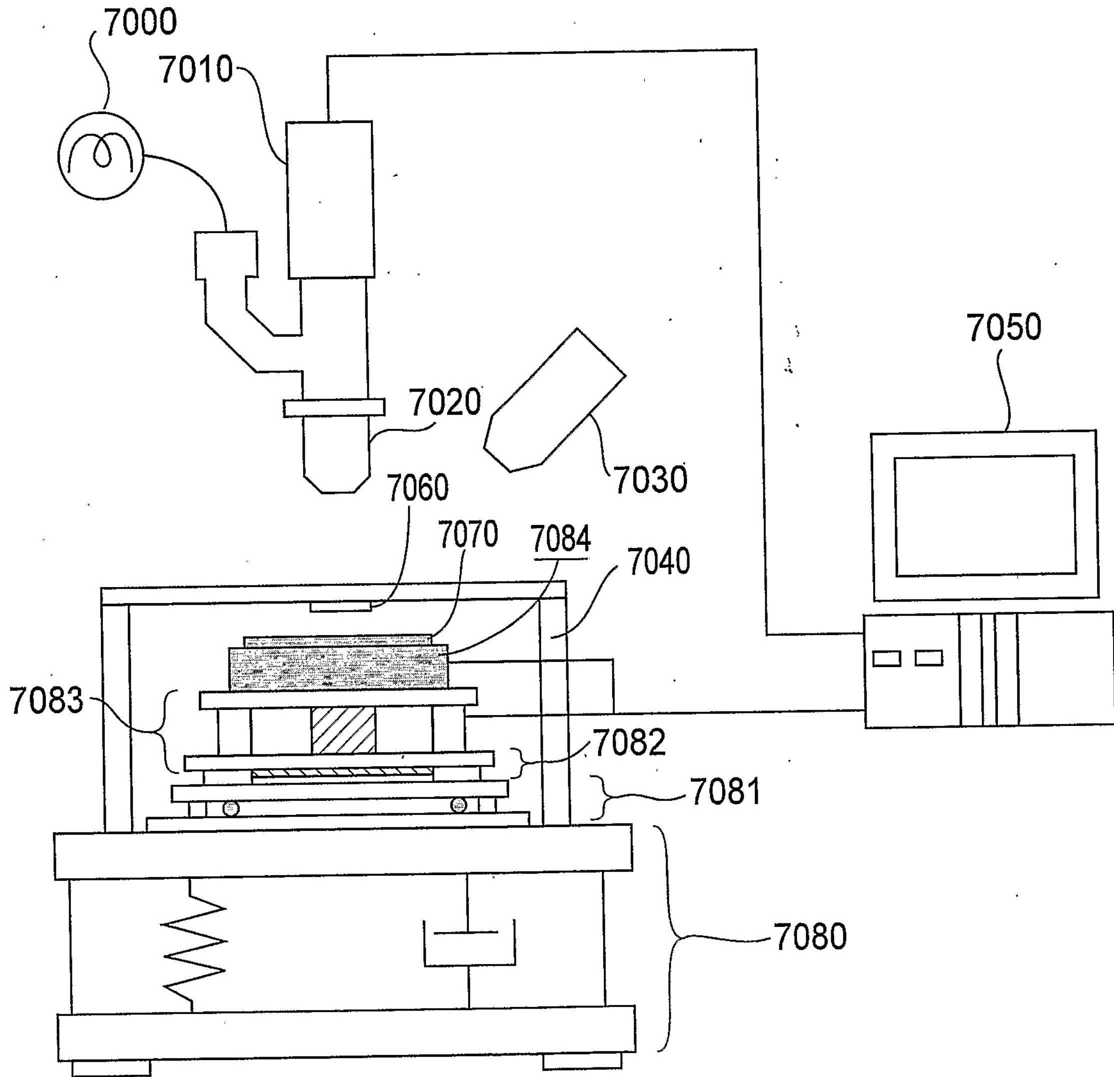


FIG.7

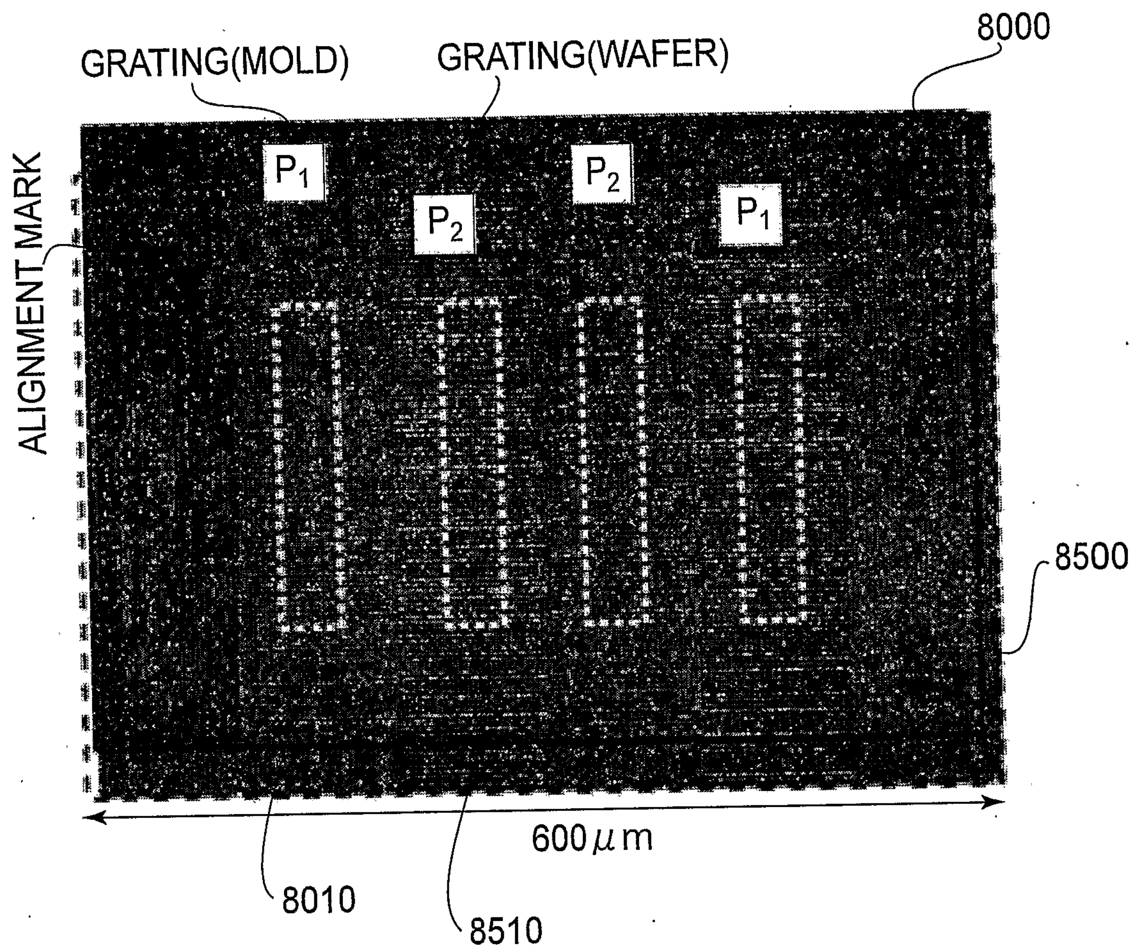


FIG.8

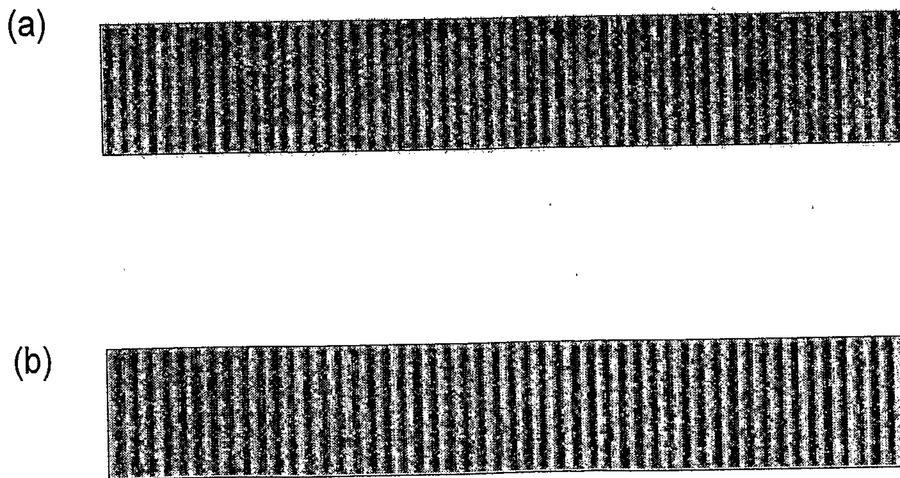


FIG.9

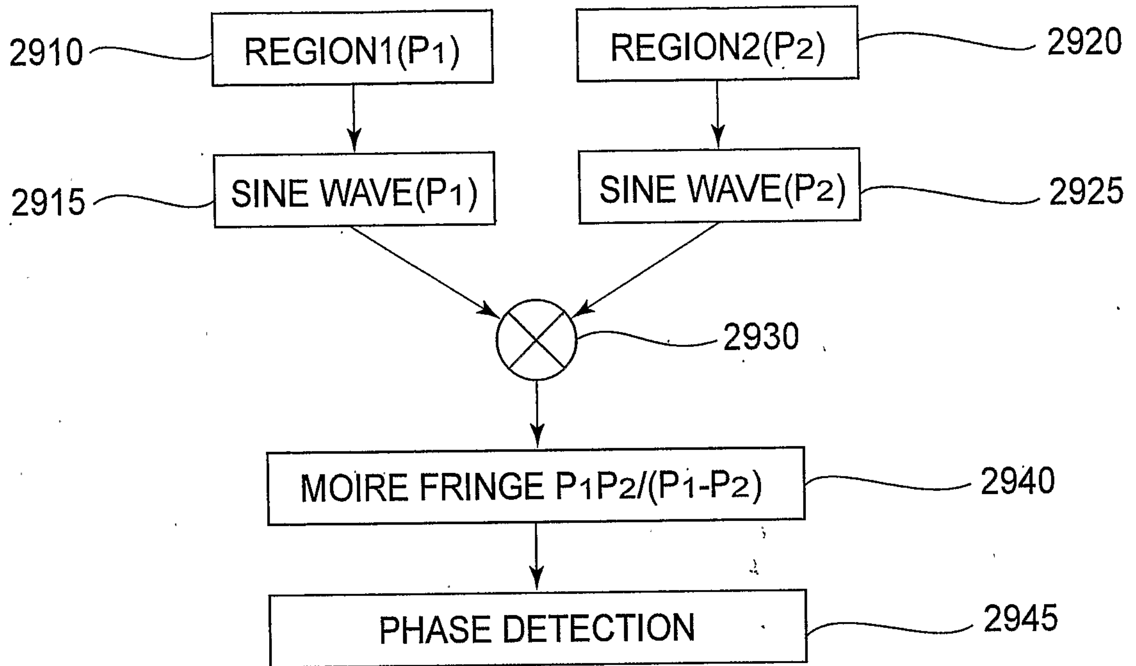


FIG.10

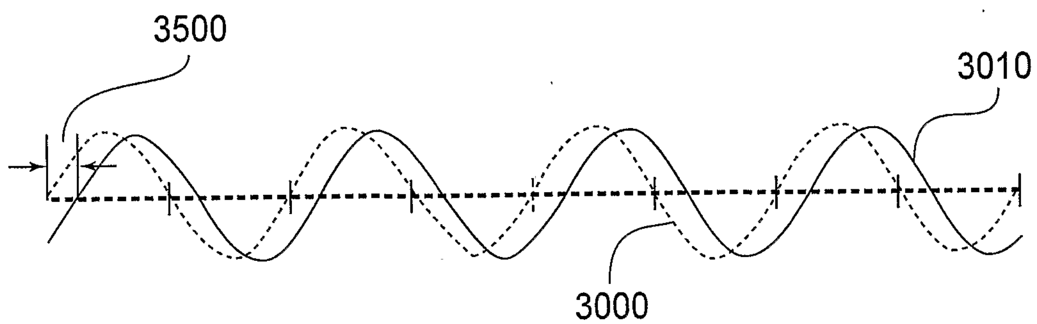


FIG.11

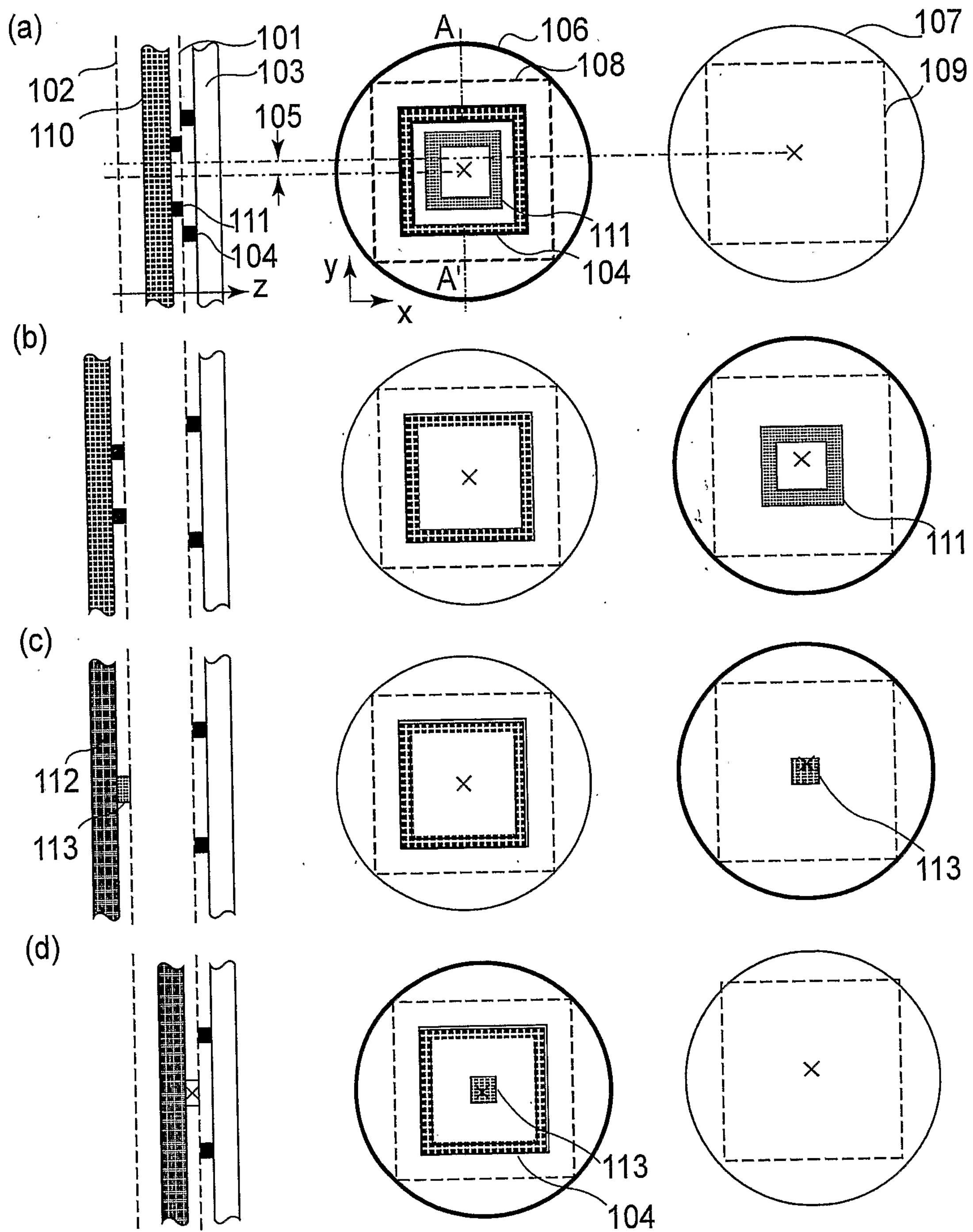
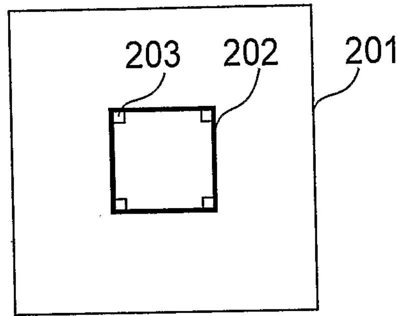
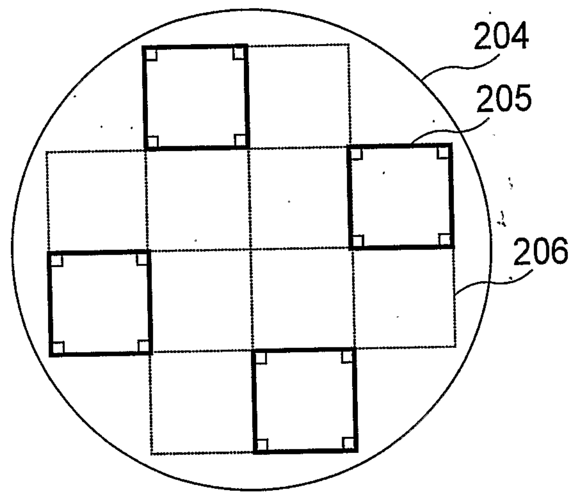


FIG.12

(a)



(b)



(c)

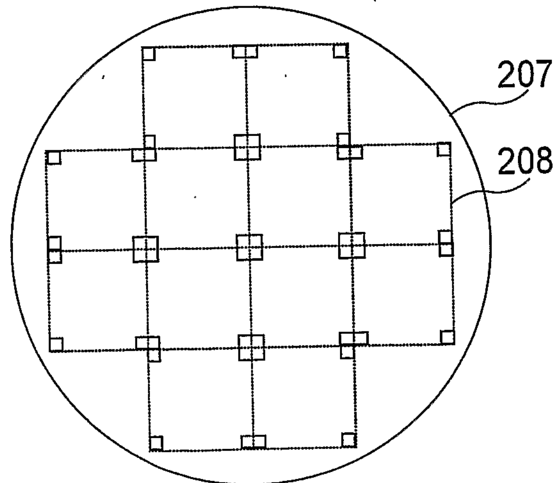


FIG.13

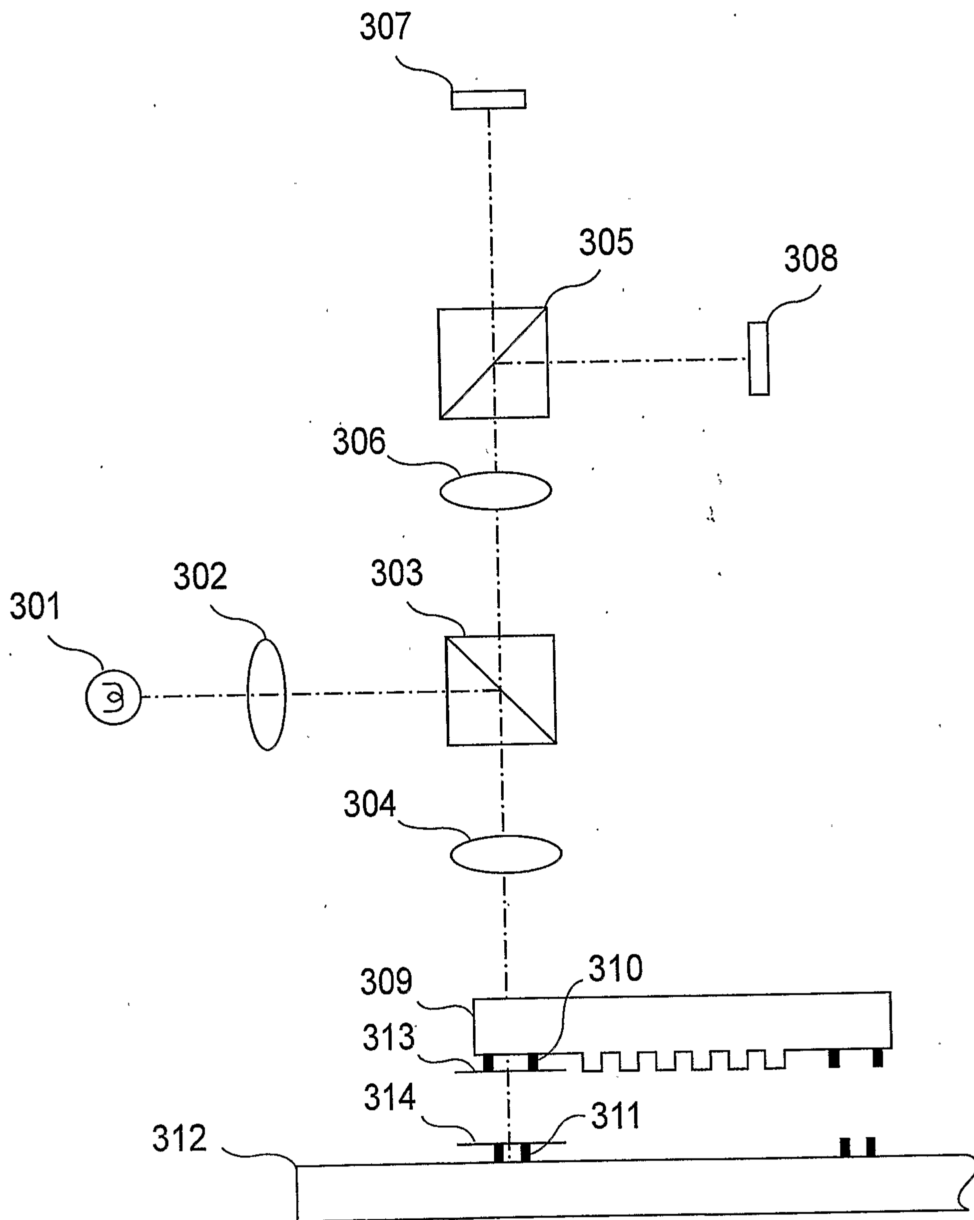


FIG.14

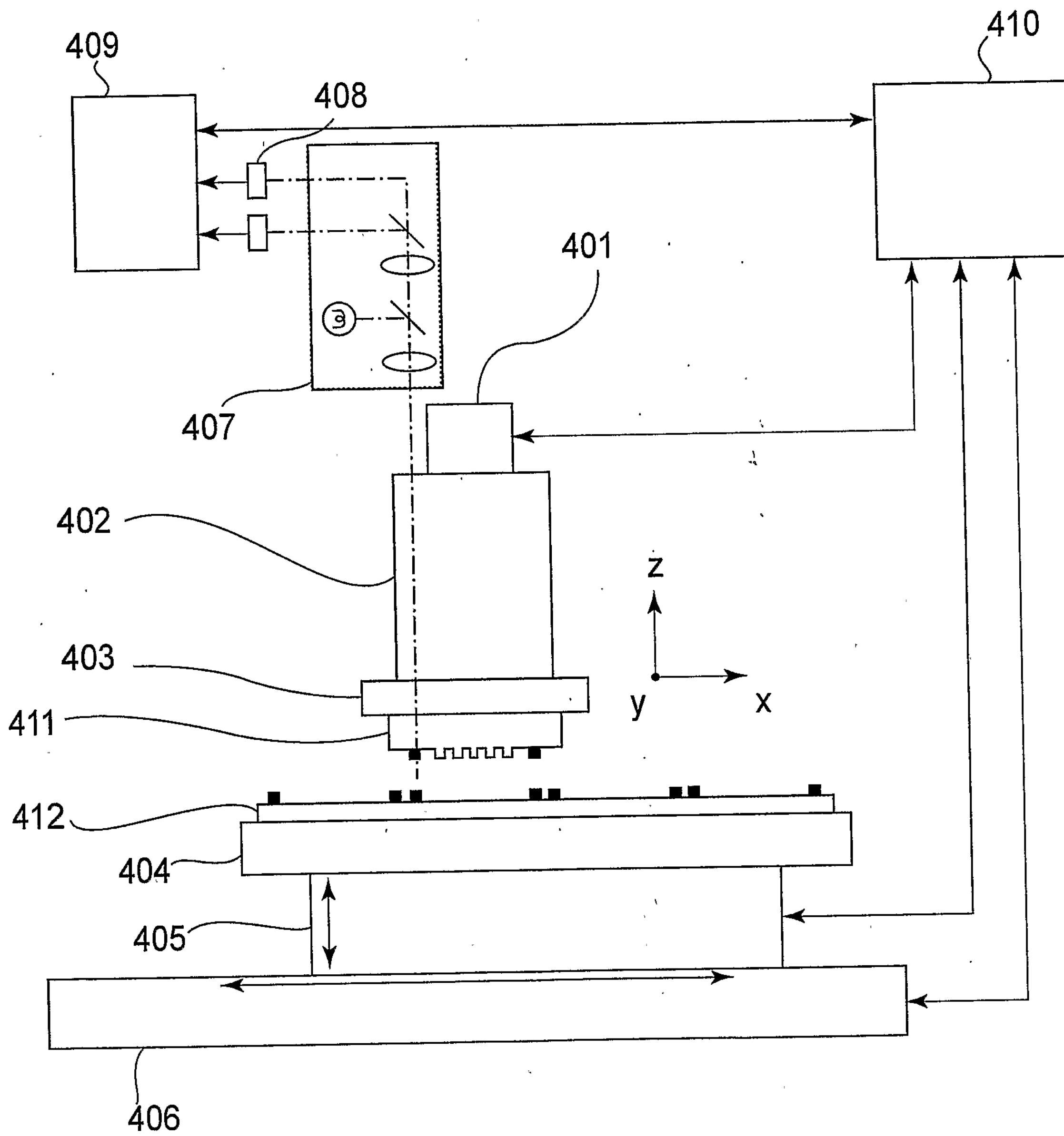


FIG.15

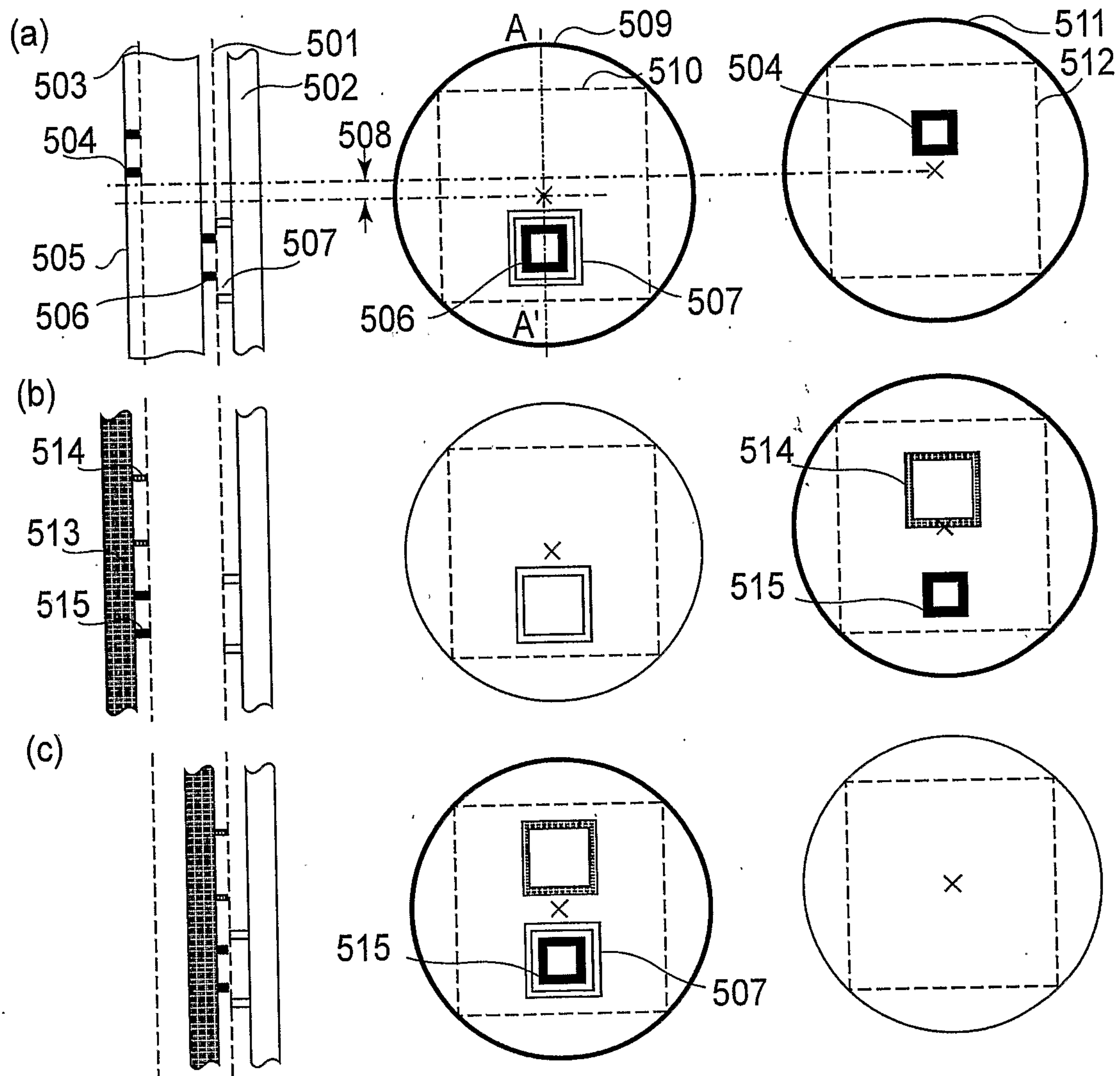


FIG.16

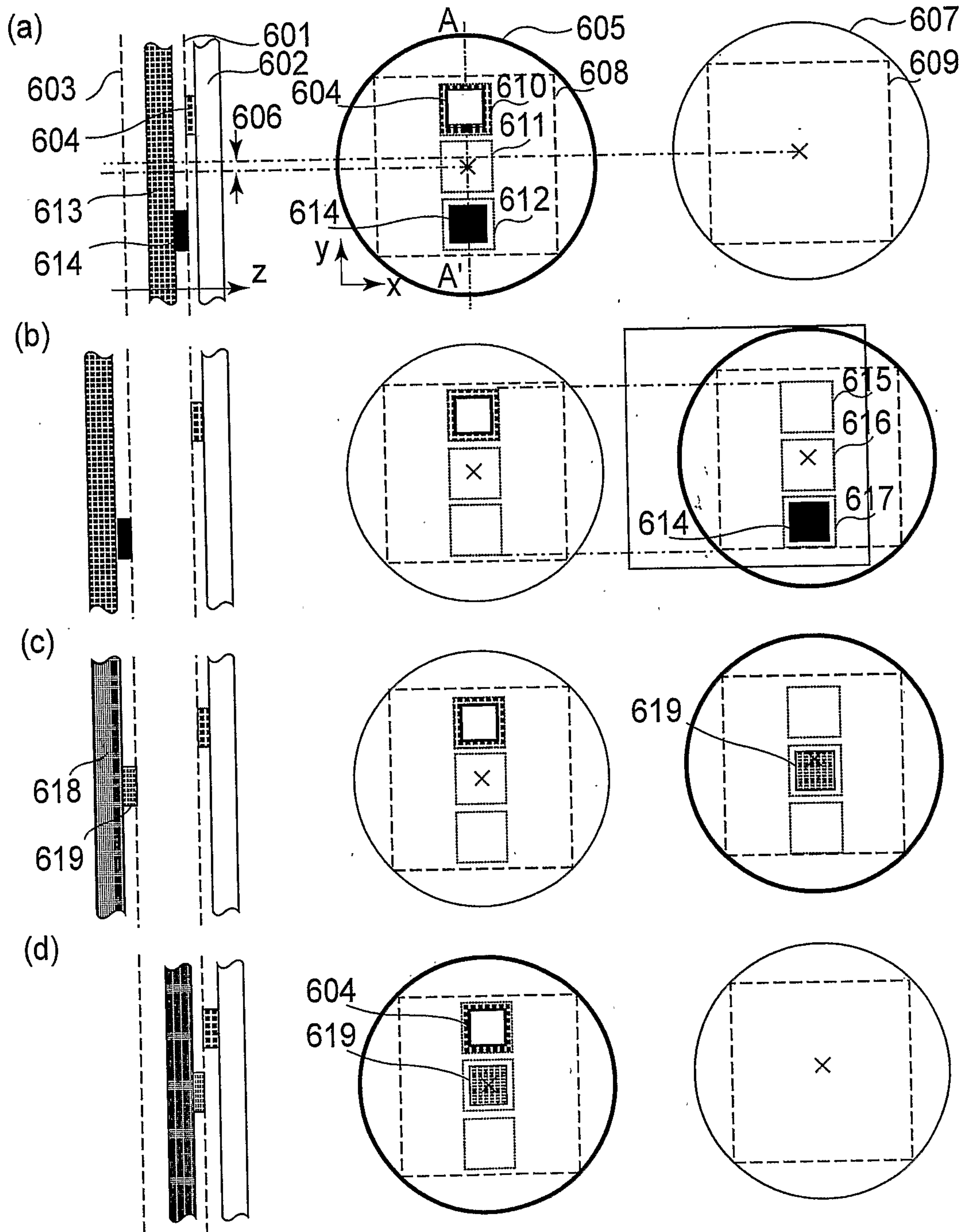


FIG.17

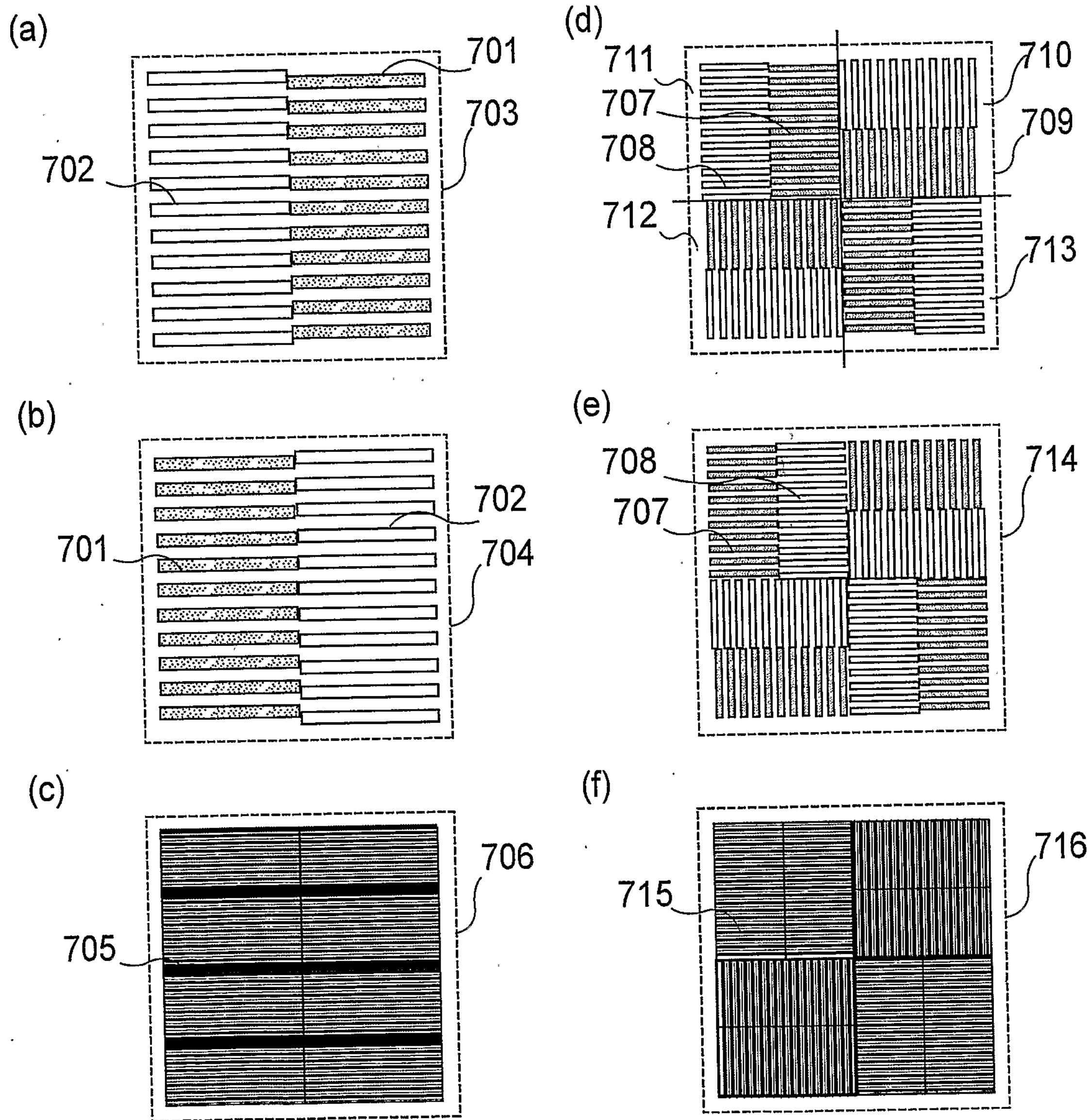


FIG.18

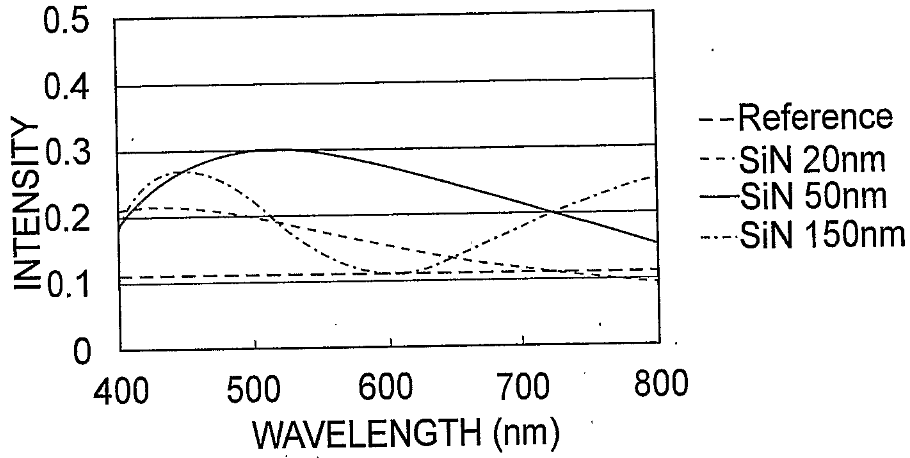


FIG.19

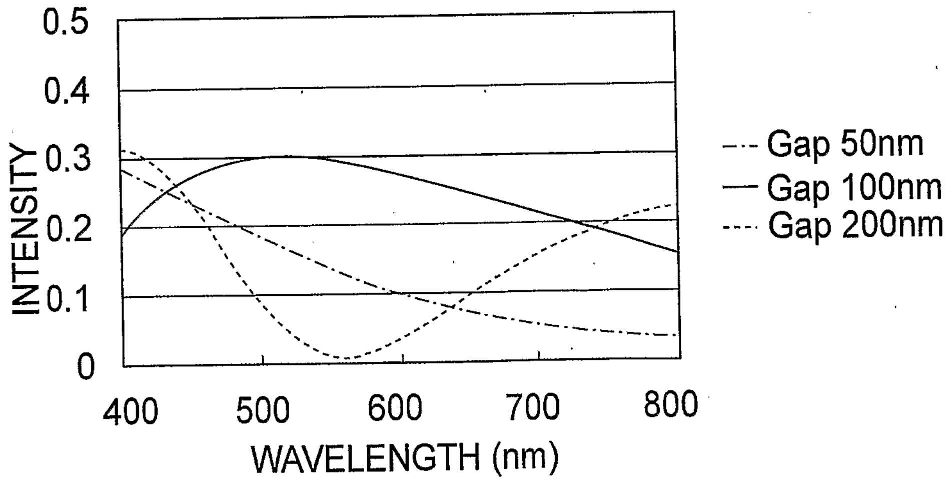


FIG.20