

REPLACED SHEETS		SG
☐ Description	: paged	to paged
☒ Claim(s)	: paged 24	to paged 31
☒ Drawing(s)	: paged	to paged
☒ Abstract	: paged 32	to paged

-1-

PROJECTION EXPOSURE APPARATUS AND
DEVICE MANUFACTURING METHOD USING THE SAME

FIELD OF THE INVENTION AND RELATED ART

- 5 This invention relates to a projection exposure apparatus and a device manufacturing method for manufacturing microdevices such as ICs, LSIs, liquid crystal devices or magnetic heads, for example, by using such a projection exposure apparatus.
- 10 In a projection exposure apparatus for manufacture of semiconductor chips such as ICs or LSIs, for example, during repetitions of projection exposure, a projection optical system absorbs a portion of exposure light energy so that it is heated.
- 15 The absorbed heat is then radiated. This causes shift of the position of the imaging plane of the projection optical system or a change of the projection magnification. Such shift of the imaging plane or change in the projection magnification may be detected
- 20 on the basis of equations with parameters such as total light quantity passing a reticle pattern, the time consumed for the exposure process and the time between successive exposures in addition to the time constant peculiar to the projection optical system.
- 25 Then, drive of a wafer stage or drive of a lens or lenses of the projection optical system or the pressure between lenses of the projection optical

system may be controlled to correct the shift of the imaging plane or the change of the projection magnification.

However, it has been found that, even if the total light quantity passing the reticle pattern is the same, in a case where a reticle having a pattern of different type is used or a phase shift reticle is used or, alternatively, in a case where an oblique illumination method is used in an illumination optical system, the light quantity distribution of the optical elements of the projection optical system differs. This results in a different change in the optical characteristic of the projection optical system and, therefore, it is not possible to detect and correct the change of the optical characteristic, such as imaging plane position or projection magnification of the projection optical system, on the basis of the equations as mentioned above. This problem may be attributable to that the light quantity distribution of the optical elements of the projection optical system differs and that the temperature distribution of the projection optical system changes.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a projection exposure apparatus by which a change in optical characteristic of a projection

optical system can be detected and corrected accurately.

It is another object of the present invention to provide a device manufacturing method for manufacturing devices by using such a projection exposure apparatus.

In accordance with an aspect of the present invention, there is provided a projection exposure apparatus, comprising: a projection optical system for projecting a pattern of a reticle onto a substrate; optical characteristic detecting means for detecting a change in optical characteristic of said projection optical system, which change may results from the projection of the reticle pattern onto the substrate through said projection optical system; and light detecting means for detecting at least one of (i) an intensity distribution of light from the reticle pattern, at a position adjacent to the reticle or adjacent to an imaging plane on which the reticle is to be imaged, and (ii) an intensity distribution of the light from the reticle pattern, at a position adjacent to a pupil plane of said projection optical system; wherein said optical characteristic detecting means is arranged to detect the amount of change in optical characteristic in accordance with the intensity distribution detected by said light detecting means.

In accordance with another aspect of the present invention, there is provided a projection exposure apparatus, comprising: a projection optical system for projecting a pattern of a reticle onto a substrate; optical characteristic detecting means for
5 detecting a change in optical characteristic of said projection optical system, which change may results from the projection of the reticle pattern onto the substrate through said projection optical system;
10 optical characteristic correcting means for substantially correcting the change in optical characteristic of said projection optical system in accordance with an output of said optical characteristic detecting means; and light detecting
15 means for detecting at least one of (i) an intensity distribution of light from the reticle pattern, at a position adjacent to the reticle or adjacent to an imaging plane on which the reticle is to be imaged, and (ii) an intensity distribution of the light from
20 the reticle pattern, at a position adjacent to a pupil plane of said projection optical system; wherein said optical characteristic detecting means is arranged to detect the amount of change in optical characteristic in accordance with the intensity distribution detected
25 by said light detecting means.

In one preferred form of the invention, said optical characteristic detecting means is arranged to

detect at least one of the amount of change of said imaging plane of said projection optical system and the amount of change of projection magnification.

In another preferred form of the invention,
5 said optical characteristic correcting means is arranged to correct at least one of the amount of change in said imaging plane of said projection optical system and the amount of change in projection magnification.

10 Preferably, said optical characteristic detecting means and said optical characteristic correcting means are arranged to detect and correct the change of said imaging plane of said projection optical system and the change of projection
15 magnification thereof.

In a further preferred form of the invention,
said light detecting means includes first light detector means having a light detecting surface adjacent to said imaging plane of said projection
20 optical system, for detecting a light intensity distribution adjacent to the reticle, and second light detector means having a light detecting surface at a position away from said imaging plane of said projection optical system, for detecting a light
25 intensity distribution adjacent to the pupil plane of said projection optical system.

In a still further preferred form of the

invention, said light detecting means includes a light blocking plate with a pinhole disposed adjacent to said imaging plane, and a plurality of photoelectric converting elements arrayed at a position away from
5 said imaging plane for detecting light passing through the reticle pattern and through said projection optical system and coming from said light blocking plate, wherein the light intensity distribution adjacent to the pupil plane of said projection optical
10 system is determined on the basis of an output distribution of said photoelectric converting elements, wherein the light intensity adjacent to the reticle is determined on the basis of the sum of outputs of said photoelectric converting elements, and
15 wherein said light blocking plate and said photoelectric converting elements are movable as a unit along said imaging plane.

In a yet further aspect of the present invention, a projection exposure apparatus such as
20 above is used to print a device pattern of a reticle on a workpiece such as a silicon wafer or a glass substrate, for example, for accurate manufacture of devices such as ICs, LSIs, CCDs, liquid crystal elements or magnetic heads, for example.

25 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.

5 BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic view of a projection exposure apparatus according to one embodiment of the present invention.

10 Figure 2 is a plan view for explaining a modified form of the projection exposure apparatus of Figure 1.

Figures 3A, 3B and 3C are schematic views for explaining examples of a split sensor.

15 Figure 4 is a flow chart of device manufacturing processes.

Figure 5 is a flow chart of a wafer process in a portion of the flow of Figure 4.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

20 Figure 1 is a schematic view showing one embodiment of the present invention, wherein the invention is applied to a step-and-repeat type projection exposure apparatus for manufacture of microdevices such as ICs, LSIs, CCDs, liquid crystal
25 elements or magnetic heads, for example.

Denoted in Figure 1 at 1 is an illumination system, and denoted at 2 is a reticle having a device

pattern formed thereon. Denoted at 3 is a reticle stage, and denoted at 4 is a projection lens system for projecting the device pattern of the reticle 2 in a reduced scale. Denoted at 5 is a wafer on which the device pattern of the reticle is to be transferred or printed, and denoted at 6 is a wafer chuck for holding the wafer 5. The wafer chuck 6 is movable along the direction of an optical axis 25. Denoted at 7 is an X-Y stage for holding the wafer chuck 6. The X-Y stage 7 is movable two-dimensionally along a plane perpendicular to the optical axis 25. Denoted at 8 is a base on which the projection lens system 4 and the X-Y stage 7, for example, are mounted.

Denoted at 9 is a stop of the illumination system 1. The stop 9 has an opening which is variable in size and in shape. Denoted at 10 is a driving mechanism for changing the size or shape of the opening of the stop 9, to thereby change the numerical aperture (N.A.). Denoted at 11 is a certain lens of the projection lens system 4, which lens 11 is movable along the optical axis 25 direction. Denoted at 12 is a driving mechanism for moving and displacing the lens 11 along the optical axis 25 direction, to thereby change the projection magnification of the projection lens system 4. Denoted at 13 is a stop (pupil) of the projection lens system 4. The stop 13 is at a position optically conjugate with the stop 9. The

stop 13 has an opening which is variable in size.

Denoted at 14 is a driving mechanism for changing the size of the opening of the stop 13, to thereby change the numerical aperture (N.A.).

5 Denoted at 15 and 16 are components for detecting the position (level) of the wafer 5 surface with respect to the optical axis 25 direction. More specifically, denoted at 15 is an illumination device for illuminating the wafer 5, and denoted at 16 is a
10 light receiving device for receiving reflected light from the wafer 5 surface and for producing a signal corresponding to the position of the wafer 5 surface. Denoted at 17 is a controller for controlling the components 15 and 16.

15 Denoted at 18 is a reflector fixedly mounted on the X-Y stage 7, and denoted at 19 is a laser interferometer for projecting a laser beam to the reflection surface of the reflector 18 and for
20 detecting the amount of displacement of the X-Y stage 7. Denoted at 20 is a driving mechanism for controlling movement of the X-Y stage 7 in response to the output of the laser interferometer.

 The driving mechanism 20 receives information related to the level of the wafer 5 surface, from the
25 controller 17. Then, it serves to move the wafer chuck 6 along the optical axis direction, such that the wafer 5 surface is brought into registration with

the imaging plane on which the device pattern of the reticle 2 is to be imaged by the projection lens system 4.

Denoted at 21 is a light blocking plate
5 having a central pinhole, and denoted at 22 is an array of photoelectric converting elements such as CCDs (the array hereinafter will be referred to as "CCD 22"). The light blocking plate 21 is so set that the surface thereof is at the same level of the wafer
10 5 surface, and it is disposed adjacent to the imaging plane of the device pattern of the reticle 2 through the projection optical system 4. The CCD 22 is disposed at a position which is below and is at a predetermined distance from the light blocking plate
15 21, so that it receives the light passing through the pinhole of the light blocking plate 21.

The CCD 22 is at a position spaced away from the imaging plane of the reticle device pattern. This position is such a position about which a light
20 intensity distribution that corresponds to the light intensity distribution of diffraction light from the device pattern of the reticle 2 as produced at the opening of the stop 13 of the projection optical system 4, is produced. The light blocking plate 21
25 and the CCD 22 are fixedly mounted on the X-Y stage 7 as a unit therewith. Thus, by moving the X-ray stage 7, the pinhole of the light blocking plate 21 is

positioned sequentially at different positions within the imaging plane and, thus, detection of light intensity or light intensity distribution is enabled at these positions.

5 Denoted at 23 is a controller which serves to drive the CCD 22, to receive outputs from the CCD 22, to detect the light intensity distribution of the device pattern image as formed on the imaging plane (which corresponds to the intensity distribution,
10 adjacent to the reticle 2, of the light passed through the device pattern of the reticle 2) and to detect the light intensity distribution at the opening of the stop 13 as formed on the light receiving surface of the CCD 22 (which corresponds to the light intensity
15 distribution at the pupil of the projection optical system 4).

The light intensity distribution of the device pattern image is detected by moving the X-Y state 7 to sequentially place the pinhole of the light
20 blocking plate 21 at different positions within the imaging plane of the device pattern and by detecting the sum of outputs of the picture elements of the CCD 22 at these positions. The light intensity distribution at the opening of the stop 13 is detected
25 by moving the X-Y stage 7 to sequentially place the pinhole of the light blocking plate 21 at different positions within the imaging plane of the device

pattern and by detecting an average of the light intensity distributions obtainable from the outputs of the CCD 22 at these positions.

In addition to the light intensity
5 distribution of the device pattern image, the controller 23 produces, from the outputs of the CCD 22, the information related to the total light quantity of the light passed through the device pattern of the reticle 2.

10 Denoted at 24 is a main controller for controlling the elements denoted at 10, 12, 14, 17, 20 and 23. Various data such as the information related to the open and closed periods of an exposure controlling shutter (not shown) of the illumination
15 system 1 (that is, the time period t consumed for the exposure and time period t' between successive exposure periods), the information related to the light intensity distribution of the device pattern image from the controller 23, and the information
20 related to the light intensity distribution at the opening of the stop 13 from the controller 23, are all applied to this main controller 24.

As a reticle 2 is set in the exposure apparatus of Figure 1 and the size and shape of each
25 of the stops 9 and 13 are determined by the mechanism 12 or 14 and when the exposure process is repeatedly performed to different shots of a wafer 5 and then to

successive wafers, the controller 24 calculates a
change ΔF of the position of the imaging plane of the
device pattern through the projection optical system 4
resulting from the repetition of exposures as well as
5 a change $\Delta\beta$ of the device pattern projection
magnification of the projection lens system 4 also
resulting from the repetition of exposures, this being
performed in accordance with equations (1) and (2)
below. This calculation is done by using equations
10 which are obtainable by modifying conventionally used
correction equations by adding parameters dependent
upon the light intensity distribution of diffraction
light.

15
$$\Delta F = \Delta F_1 + \Delta F_2 \quad \dots(1)$$

$$\Delta F_1 = SF \cdot QD \cdot Da \cdot Db \cdot DT$$

$$\Delta F_2 = -\Delta F' \cdot \exp(-k_F \cdot t)$$

20
$$\Delta\beta = \Delta\beta_1 + \Delta\beta_2 \quad \dots(2)$$

$$\Delta\beta_1 = SB \cdot QD \cdot Da \cdot Db \cdot DT$$

$$\Delta\beta_2 = -\Delta\beta' \cdot \exp(-K_B \cdot t)$$

In these equations, SF and SB are
proportional constants; QD is a parameter
25 corresponding to the total quantity of light passed
through the device pattern; Da is a parameter
dependent upon the light intensity distribution of the

device pattern image (i.e., the distribution of light transmissivity of the device pattern of the reticle 2); D_b is a parameter dependent upon the light intensity distribution at the opening of the stop 13 (i.e., the light intensity distribution at the pupil plane of the projection optical system 4, of the light from the reticle 2); K_F and K_B are parameters which represent the heat conductivity of the projection lens system 4; DT is the ratio of time period, within unit time in calculation, in which period the shutter is kept open; $\Delta F'$ and $\Delta \beta'$ are the amount of change of the imaging plane and the amount of change of the magnification, respectively, of the projection lens system as calculated in the preceding unit time just before; ΔF_1 and $\Delta \beta_1$ each is the amount of change per unit time of the projection lens system due to heat absorption; and ΔF_2 and $\Delta \beta_2$ each is the amount of change per unit time of the projection lens system 4 due to heat radiation. The changes ΔF_2 and $\Delta \beta_2$ may be expressed in the form of linear coupling of plural terms. The values of D_a and D_b may be determined beforehand, through experiments, for example, in relation to various light intensity distributions to be produced by the controller 23. The thus determined data may be stored into the controller 24, such that corresponding one of the stored ones in the controller 24 may be used.

Variable Da and Db may be determined by calculation, using calculation formulae memorized in the controller 24. Such calculation formulae may be determined by experiments, for example, using several
5 typical type reticles. As an example, as for the formula in relation to the variable Db, the following equation may be used:

$$Db = (aE_1 + bE_2 + cE_3 + dE_4 + eE_5) / (E_1 + E_2 + E_3 + E_4 + E_5)$$

10

The above equation may be used in an occasion where the light intensity distribution at the opening of the stop 13 is detected by using a split sensor (Figure 3A) to be described later or in a case where five
15 split zones are defined in the light receiving surface of the CCD 22 (such as the split sensor illustrated in Figure 3A) so that evaluation of the light intensity distribution at the opening of the stop 13 may be done with respect to each zone. In the equation above, E_1 ,
20 E_2 , E_3 , E_4 and E_5 represent the magnitudes of the outputs (light intensities) as produced by the photoelectric converting portions S_1 , S_2 , S_3 , S_4 and S_5 of the split sensor of Figure 3A. Also, symbols a, b, c, d, and e are coefficients. The values of these
25 coefficients a, b, c, d and e may determined from experimentally determined Db and a volume of data related to E_1 , E_2 , E_3 , E_4 and E_5 and by applying the

least square method to this equation.

As regards the calculation formula related to the variable D_a , similar equation related to the light transmissivity distribution of the device pattern of the reticle 2 may be used.

At every unit time, the calculation is performed. Thus the calculation is repeated. Therefore, the amount of change as obtainable from the calculation changes along a curve whose envelope can be represented by a function of natural logarithm.

In the embodiment, every time a shot on the wafer 5 is exposed, the error ΔF of the position of the imaging plane of the device pattern and the error $\Delta\beta$ of the projection magnification of the device pattern are calculated by using equations (1) and (2) above. Then, by using the components 12, 17 and 20, the position of the lens 11 and/or the position of the wafer 5 surface is adjusted so as to correct the error ΔF of the position of the imaging plane of the device pattern and the error $\Delta\beta$ of the projection magnification. The surface of the wafer 5 is thus brought into the position corresponding to the result of adding the error ΔF to the original position of the imaging plane of the device pattern of the projection lens system 4.

In this embodiment, detection of the total light quantity of the light passed through the device

pattern of the reticle 2, and detection of the distribution of the light transmissivity of the device pattern of the reticle 1 (the light intensity distribution of the device pattern image) as well as
5 detection of the intensity distribution at the pupil plane of the projection lens system 4 of the light from the device pattern of the reticle 2 (i.e., the light intensity distribution at the opening of the stop 13), are all performed every time the reticle 2
10 is replaced by a different reticle having a different device pattern. The parameters obtainable from the results are stored into the controller 24 as reticle data related to the reticle used. After this, when the same reticle is loaded into the exposure
15 apparatus, corresponding data having been memorized is read out and is used for the calculation of the error ΔF of the position of the imaging plane and the error $\Delta \beta$ of the projection magnification.

20 In this embodiment, as described above, for calculation of the error ΔF in the position of the imaging plane and the error $\Delta \beta$ in the magnification, parameters dependent upon the light intensity distribution of the device pattern image (distribution of the light transmissivity of the device pattern of
25 the reticle 2) as well as parameters D_b dependent upon the light intensity distribution at the opening of the stop 13 (light intensity distribution at the pupil

plane of the projection lens system 4 of the light
from the reticle 2) are used. It is therefore
possible to obtain exact values of the change ΔF of
position of the imaging plane and the change $\Delta\beta$ of
5 magnification, while taking into account the intensity
distribution of the light which comes from the reticle
pattern and enters the projection optical system. As
a result, it is possible to perform the projection
exposure while accurately correcting the change in
10 position of the imaging plane and the change in
projection magnification.

The error ΔF in position of the imaging plane
of the device pattern and the error $\Delta\beta$ in projection
magnification may be corrected by using a known
15 method. For example, the error ΔF in position of the
imaging plane may be corrected by changing the focal
length of the projection lens system 4 or by moving,
upwardly or downwardly, the reticle 2 and the
projection lens system 4 as a unit along the optical
20 axis 25 direction. The error $\Delta\beta$ of projection
magnification may be corrected by changing the focal
length of the projection lens system 4 or by moving
the reticle 2 upwardly or downwardly along the optical
axis 25 direction. For changing the focal length of
25 the projection lens system 4, a particular lens or
lenses of the projection lens system 4 may be
displaced along the optical axis 25 or, alternatively,

the interspace between adjacent lenses of the projection lens system 4 may be shielded to provide a gas-tight chamber (air lens) and the inside pressure of the chamber may be changed.

5 In this embodiment, both a change in position of the imaging plane and a change in projection magnification of a projection optical system are detected and corrected. However, only one of them may be detected and corrected.

10 Further, while in this embodiment a change in position of the imaging plane of the device pattern and a change in projection magnification are detected and corrected, the concept of the present invention is applicable also to detection and correction of a
15 change in aberration of a projection optical system such as curvature of image field, for example.

 Furthermore, in the embodiment described above, both of distribution of light transmissivity of a device pattern of a reticle 2 and intensity
20 distribution at the pupil plane of the projection lens system 4 of the light from the device pattern of the reticle 2, are performed and then error calculation is performed by using both of the parameters D_a and D_b .
25 However, only one of these intensity distributions may be detected and the error calculation may be done by using only one of these parameters. In that occasion, the other parameter may be held fixed at 1 or any

other value.

Still further, while in this embodiment the projection lens system 4 is used for projection of a device pattern, the invention is applicable also to a
5 case where a projection mirror system is used for projection of a device pattern or a case where a projection mirror and lens system (cata-dioptic system) is used for projection of a device pattern.

Also, while in this embodiment the invention
10 is applied to a step-and-repeat type projection exposure apparatus, the invention is applicable also to a step-and-scan type scanning projection exposure apparatus.

The intensity distribution at the pupil plane
15 of the projection lens system 4 of the light from the device pattern, may be detected by changing the size of the opening of the stop 13 sequentially and stepwise by using the mechanism 14 and then by detecting the total sum of the outputs of the elements
20 of the CCD 22 at all steps. In that occasion, the CCD 22 may be replaced by a photodiode.

As regards the CCD 22, either a one-dimensional CCD array or a two-dimensional CCD array may be used. A line sensor may be used in place of a
25 one-dimensional CCD. A split sensor such as illustrated in Figure 3A, 3B or 3C may be used in place of a two-dimensional CCD.

The light from the pinhole of the light blocking plate 21 may not be received directly. It may be received by way of an optical fiber or a lens, for example. If a lens is to be used, preferably a lens which is adapted to image the stop 13 upon the light receiving surface of the CCD 22 may be used.

Further, the structure may be modified as illustrated in Figure 2. That is, a first light detector which comprises a light blocking plate 21 with a pinhole and a CCD 22 as well as a second light detector which comprises a light blocking plate 121 with a pinhole and a photodiode 122, may be provided on the X-Y stage 7. The intensity distribution at the pupil plane of the projection lens system 4 of the light from the device pattern may be detected by means of the first light detector (21, 22), while the light intensity distribution of the device pattern image of the reticle 2 may be detected by means of the second light detector (121, 122). The outputs of these light detectors may be applied to the controller 23 of Figure 1.

Next, an embodiment of device manufacturing method according to the present invention, for manufacturing devices by using a projection exposure apparatus according to any one of the preferred forms of the present invention, will be explained.

Figure 4 is a flow chart of the sequence of

manufacturing a semiconductor device such as a semiconductor chip (e.g. IC or LSI), a liquid crystal panel or a CCD, for example. Step 1 is a design process for designing the circuit of a semiconductor device. Step 2 is a process for manufacturing a mask on the basis of the circuit pattern design. Step 3 is a process for manufacturing a wafer by using a material such as silicon.

Step 4 is a wafer process which is called a pre-process wherein, by using the so prepared mask and wafer, circuits are practically formed on the wafer through lithography. Step 5 subsequent to this is an assembling step which is called a post-process wherein the wafer processed by step 4 is formed into semiconductor chips. This step includes assembling (dicing and bonding) and packaging (chip sealing). Step 6 is an inspection step wherein operability check, durability check and so on of the semiconductor devices produced by step 5 are carried out. With these processes, semiconductor devices are finished and they are shipped (step 7).

Figure 5 is a flow chart showing details of the wafer process. Step 11 is an oxidation process for oxidizing the surface of a wafer. Step 12 is a CVD process for forming an insulating film on the wafer surface. Step 13 is an electrode forming process for forming electrodes on the wafer by vapor

deposition. Step 14 is an ion implanting process for
implanting ions to the wafer. Step 15 is a resist
process for applying a resist (photosensitive
material) to the wafer. Step 16 is an exposure
5 process for printing, by exposure, the circuit pattern
of the mask on the wafer through the exposure
apparatus described above. Step 17 is a developing
process for developing the exposed wafer. Step 18 is
an etching process for removing portions other than
10 the developed resist image. Step 19 is a resist
separation process for separating the resist material
remaining on the wafer after being subjected to the
etching process. By repeating these processes,
circuit patterns are superposedly formed on the wafer.

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 purposes of the
20 improvements or the scope of the following claims.



WHAT IS CLAIMED IS:

1. A projection exposure apparatus, comprising:
a projection optical system for projecting a
pattern of a reticle onto a substrate;

5 optical characteristic detecting means for
detecting a change in optical characteristic of said
projection optical system, which change may results
from the projection of the reticle pattern onto the
substrate through said projection optical system; and

10 light detecting means for detecting at least
one of (i) an intensity distribution of light from the
reticle pattern, at a position adjacent to the reticle
or adjacent to an imaging plane on which the reticle
is to be imaged, and (ii) an intensity distribution of
15 the light from the reticle pattern, at a position
adjacent to a pupil plane of said projection optical
system;

wherein said optical characteristic detecting
means is arranged to detect the amount of change in
20 optical characteristic in accordance with the
intensity distribution detected by said light
detecting means.

25 2. An apparatus according to Claim 1, wherein
said light detecting means is arranged to detect both
of the intensity distribution adjacent to the reticle
or upon said imaging plane and the intensity



distribution adjacent to the pupil plane of said projection optical system.

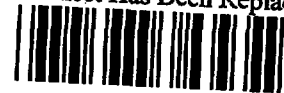
3. An apparatus according to Claim 1, wherein
5 said optical characteristic detecting means is arranged to detect at least one of the amount of change of said imaging plane of said projection optical system and the amount of change of projection magnification.

10 4. An apparatus according to Claim 3, wherein said optical characteristic detecting means is arranged to detect both of the amount of change in said imaging plane of said projection optical system
15 and the amount of change in projection magnification.

20 5. An apparatus according to Claim 2, wherein said light detecting means includes first light detector means having a light detecting surface adjacent to said imaging plane of said projection optical system, for detecting a light intensity distribution adjacent to the reticle, and second light
25 detector means having a light detecting surface at a position away from said imaging plane of said projection optical system, for detecting a light intensity distribution adjacent to the pupil plane of said projection optical system.



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-26-

5 6. An apparatus according to Claim 3, wherein
said first and second light detector means are movable
as a unit along said imaging plane, wherein the light
intensity distribution adjacent to the reticle is
determined on the basis of an output of said first
light detector means and of a movement position
thereof, and wherein the light intensity distribution
adjacent to the pupil plane of said projection optical
10 system is determined on the basis of one of (i) the
sum of outputs of the second light detector means
provided at all movement positions thereof and (ii) an
average of outputs of said second detector means
provided at all movement positions thereof.

15

20 7. An apparatus according to Claim 2, wherein
said light detecting means includes a light blocking
plate with a pinhole disposed adjacent to said imaging
plane, and a plurality of photoelectric converting
elements arrayed at a position away from said imaging
plane for detecting light passing through the reticle
pattern and through said projection optical system and
coming from said light blocking plate, wherein the
light intensity distribution adjacent to the pupil
25 plane of said projection optical system is determined
on the basis of an output distribution of said
photoelectric converting elements, wherein the light



intensity adjacent to the reticle is determined on the basis of the sum of outputs of said photoelectric converting elements, and wherein said light blocking plate and said photoelectric converting elements are
5 movable as a unit along said imaging plane.

8. An apparatus according to Claim 1, further comprising optical characteristic correcting means for substantially correcting the change in optical
10 characteristic of said projection optical system in accordance with an output of said optical characteristic detecting means.

9. An apparatus according to Claim 8, wherein
15 said light detecting means is arranged to detect both of the intensity distribution adjacent to the reticle or upon said imaging plane and the intensity distribution adjacent to the pupil plane of said projection optical system.

10. An apparatus according to Claim 8, wherein
20 said optical characteristic detecting means is arranged to detect at least one of (i) the amount of change of said imaging plane of said projection
25 optical system and (ii) the amount of change of projection magnification of said projection optical system.



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-28-

11. An apparatus according to Claim 10, wherein
said optical characteristic detecting means is
arranged to detect both of the amount of change of
5 said imaging plane of said projection optical system
and the amount of change of projection magnification
of said projection optical system.

12. An apparatus according to Claim 9, wherein
10 said light detecting means includes first light
detector means having a light detecting surface
adjacent to said imaging plane of said projection
optical system, for detecting a light intensity
distribution adjacent to the reticle, and second light
15 detector means having a light detecting surface at a
position away from said imaging plane of said
projection optical system, for detecting a light
intensity distribution adjacent to the pupil plane of
said projection optical system.

20

13. An apparatus according to Claim 12, wherein
said first and second light detector means are movable
as a unit along said imaging plane, wherein the light
intensity distribution adjacent to the reticle is
25 determined on the basis of an output of said first
light detector means and of a movement position
thereof, and wherein the light intensity distribution



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-29-

adjacent to the pupil plane of said projection optical system is determined on the basis of one of (i) the sum of outputs of the second light detector means provided at all movement positions thereof and (ii) an
5 average of outputs of said second detector means provided at all movement positions thereof.

14. An apparatus according to Claim 9, wherein said light detecting means includes a light blocking
10 plate with a pinhole disposed adjacent to said imaging plane, and a plurality of photoelectric converting elements arrayed at a position away from said imaging plane for detecting light passing through the reticle pattern and through said projection optical system and
15 coming from said light blocking plate, wherein the light intensity distribution adjacent to the pupil plane of said projection optical system is determined on the basis of an output distribution of said photoelectric converting elements, wherein the light
20 intensity adjacent to the reticle is determined on the basis of the sum of outputs of said photoelectric converting elements, and wherein said light blocking plate and said photoelectric converting elements are movable as a unit along said imaging plane.
25

15. An apparatus according to Claim 10 or 11, wherein said optical characteristic correcting means



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-30-

is arranged to perform one of (i) moving the reticle
and said projection optical system along an optical
axis direction and (ii) moving the substrate along the
optical axis direction to thereby correct the change
5 of said imaging plane and to place the surface of the
substrate and said imaging plane registered.

16. An apparatus according to Claim 10 or 11,
wherein said optical characteristic correcting means
10 is arranged to change a focal distance of said
projection optical system to correct the change of
said imaging plane and to place the surface of the
substrate and said imaging plane registered.

15 17. An apparatus according to Claim 10 or 11,
wherein said optical characteristic correcting means
is arranged to move one of the reticle and a lens of
said projection optical system along an optical axis
direction to correct the change of the projection
20 magnification.

18. An apparatus according to Claim 10 or 11,
wherein said optical characteristic correcting means
is arranged to change a focal distance of said
25 projection optical system to correct the change in the
projection magnification.



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-31-

19. A device manufacturing method for
manufacturing a device by use of a projection exposure
apparatus as recited in any one of Claims 1 - 18.

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ABSTRACT OF THE DISCLOSURE

A projection exposure apparatus including a projection optical system for projecting a pattern of a reticle onto a substrate, an optical characteristic
5 detecting device for detecting a change in optical characteristic of the projection optical system, which change may results from the projection of the reticle pattern onto the substrate through the projection optical system, and a light detecting device for
10 detecting at least one of (i) an intensity distribution of light from the reticle pattern, at a position adjacent to the reticle or adjacent to an imaging plane on which the reticle is to be imaged, and (ii) an intensity distribution of the light from
15 the reticle pattern, at a position adjacent to a pupil plane of the projection optical system, wherein the optical characteristic detecting device is arranged to detect the amount of change in optical characteristic in accordance with the intensity distribution detected
20 by the light detecting device.

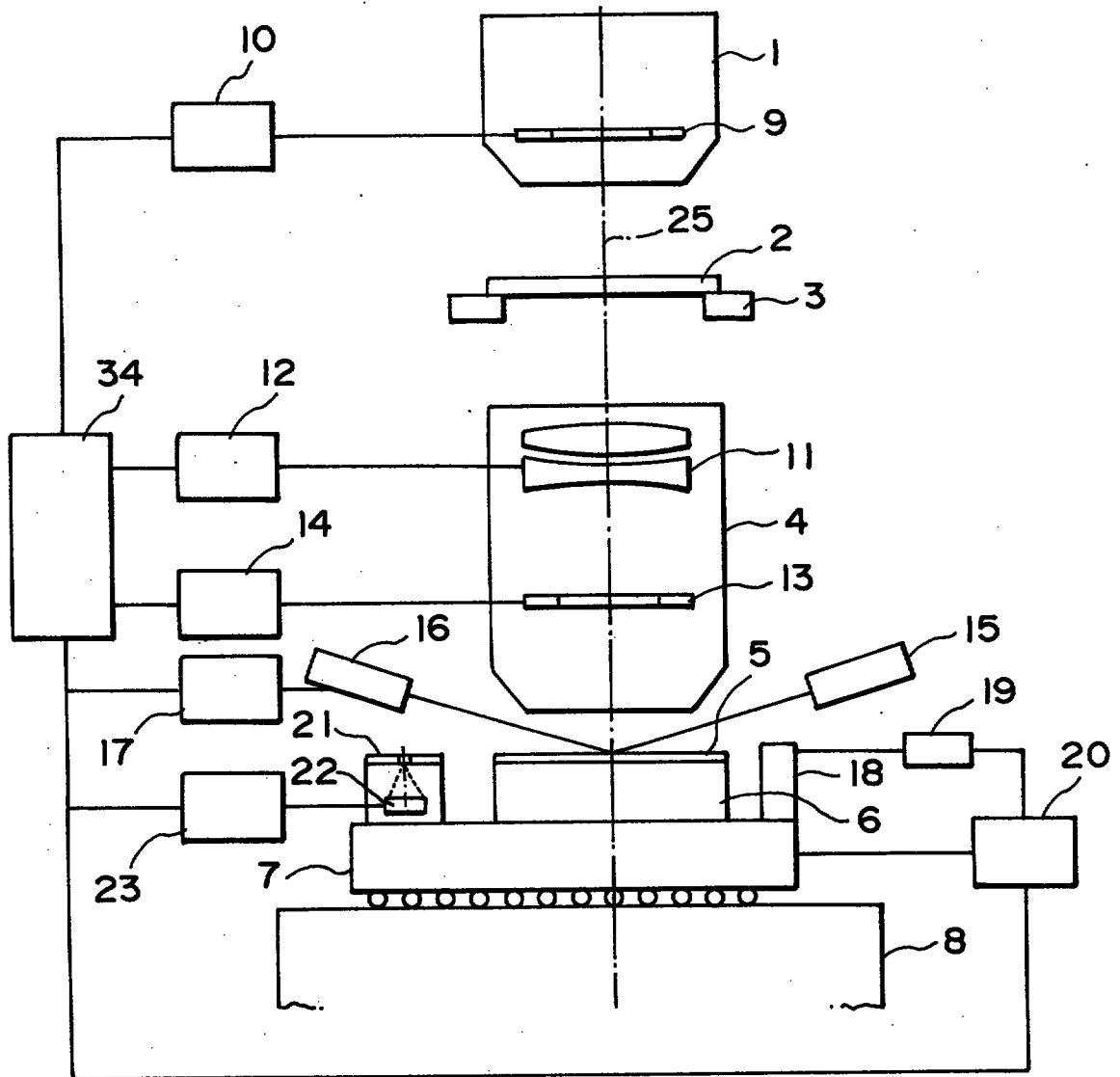


FIG. 1

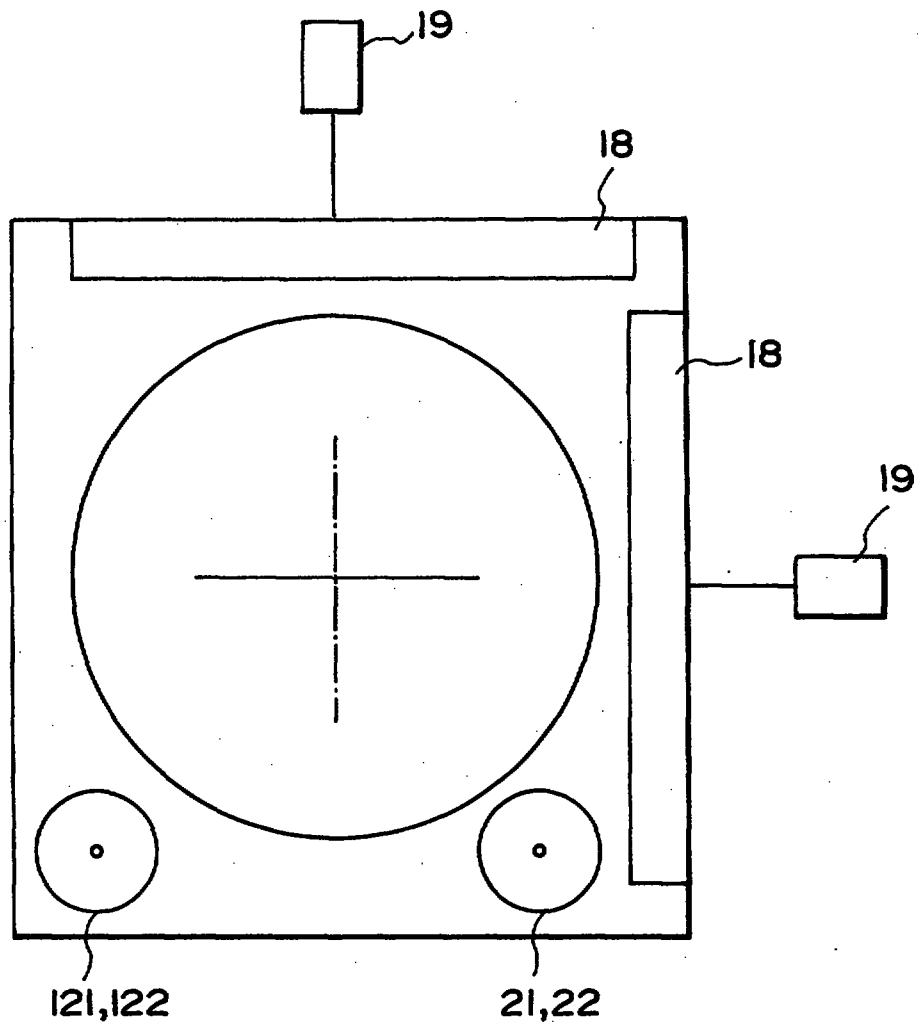


FIG. 2

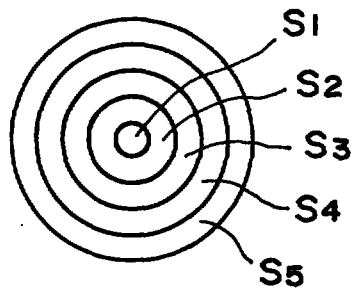


FIG. 3A

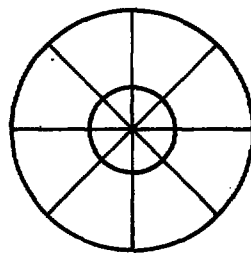


FIG. 3B

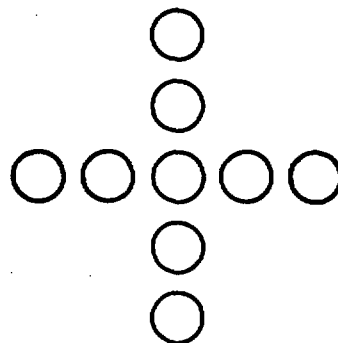


FIG. 3C

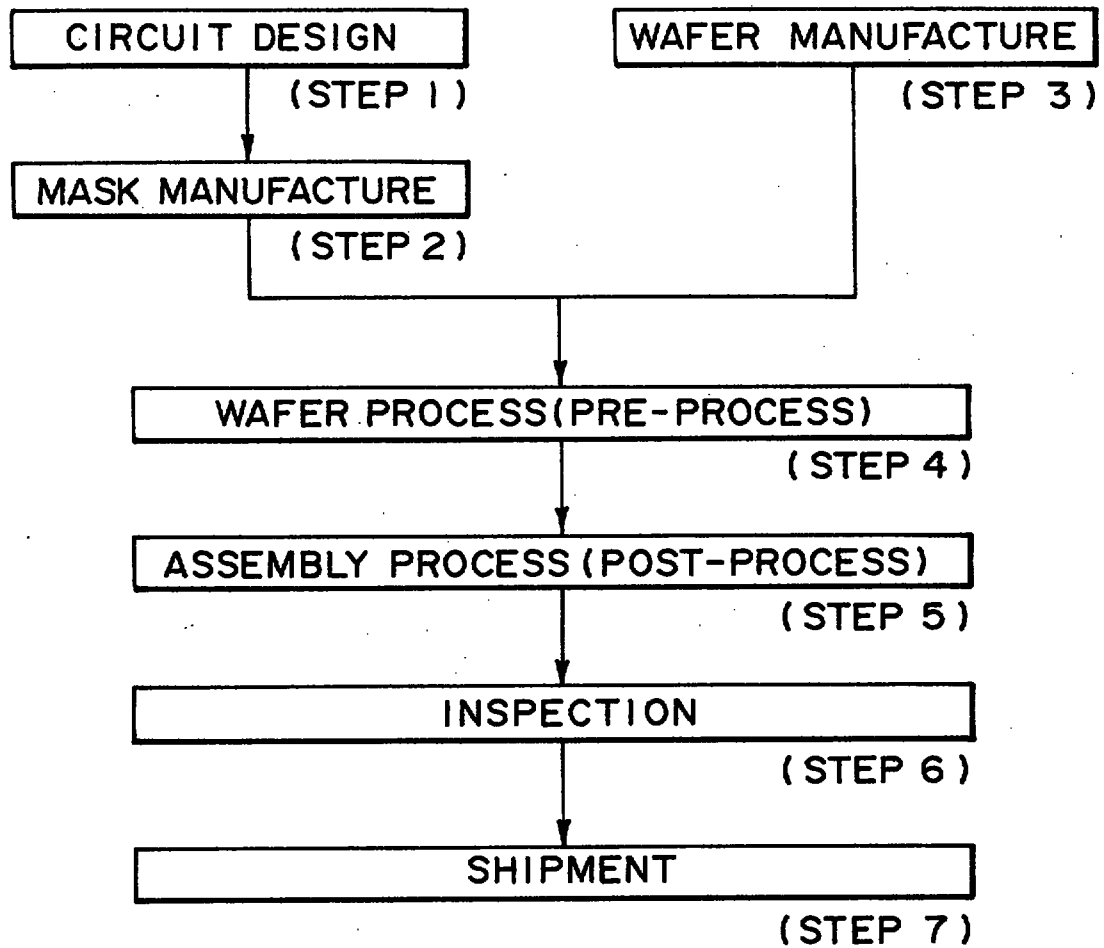
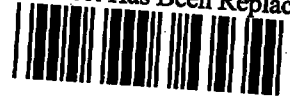


FIG. 4

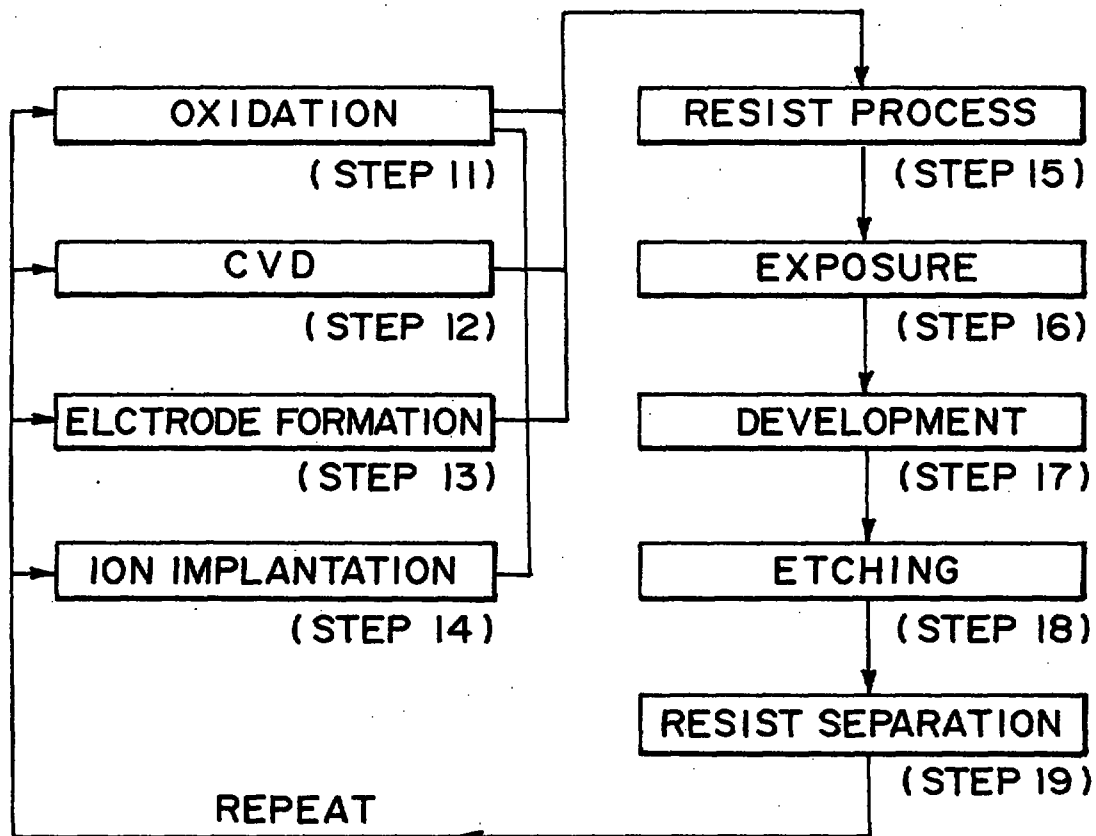
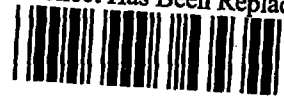


FIG. 5

REPLACEMENT SHEETS		SG
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☒	Drawing(s)	: paged 1... to paged 5...
☒	Abstract	: paged to paged
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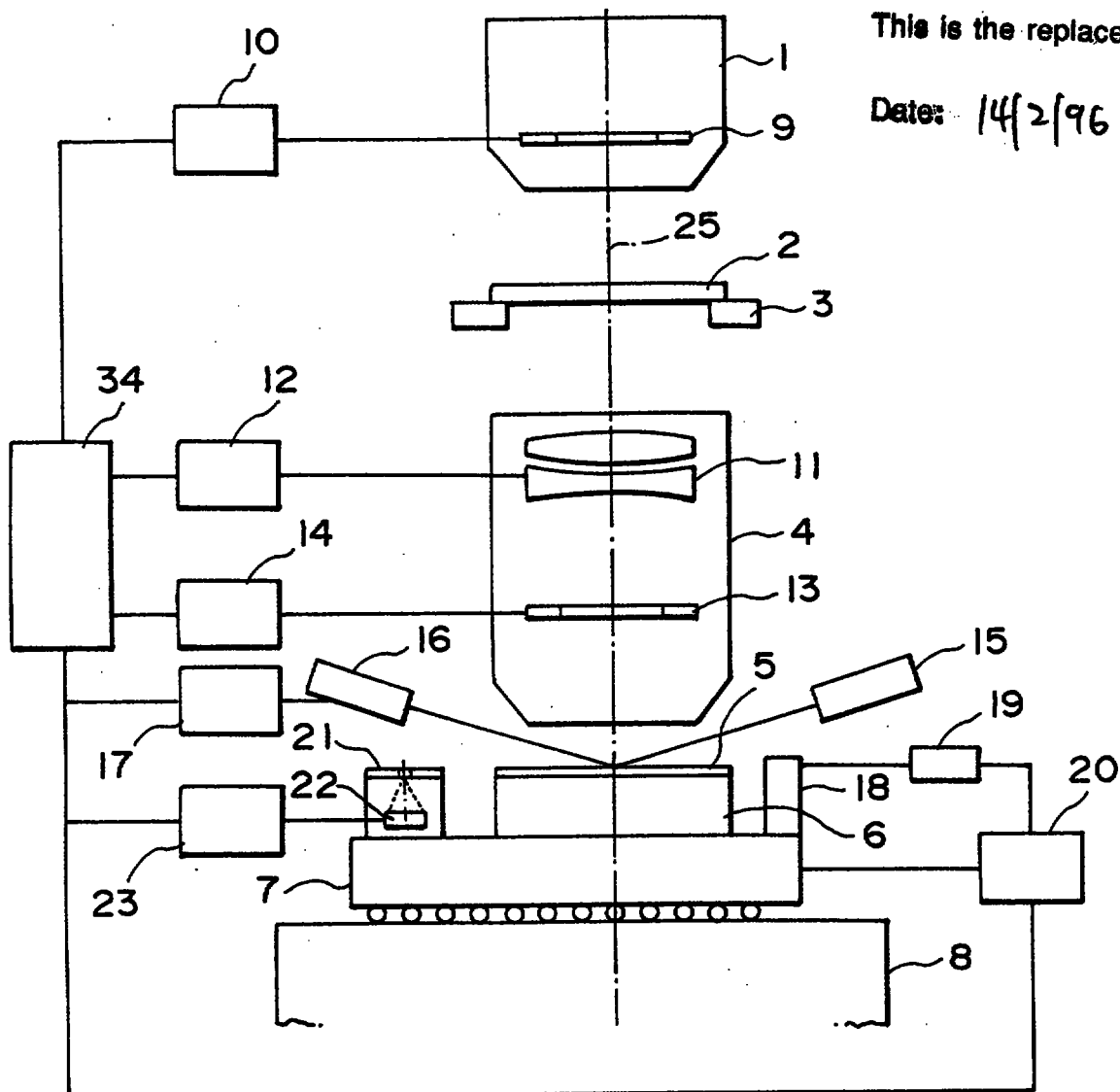


FIG. 1

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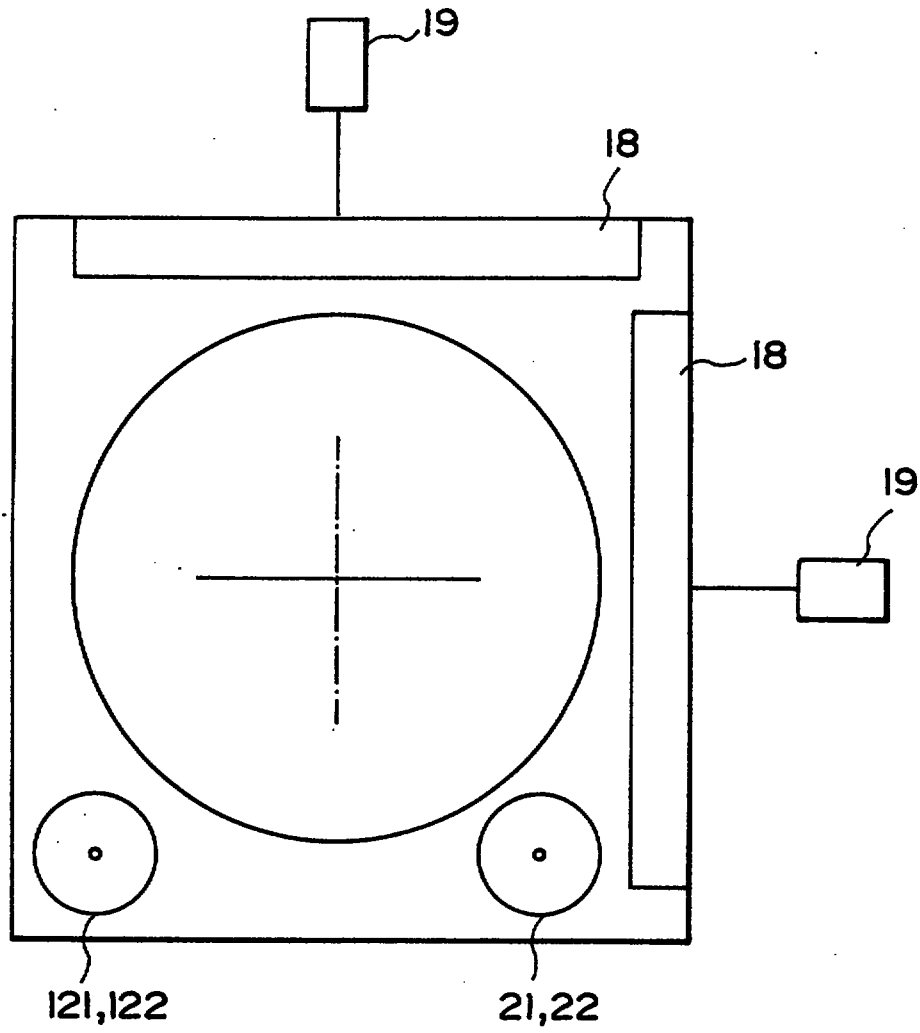
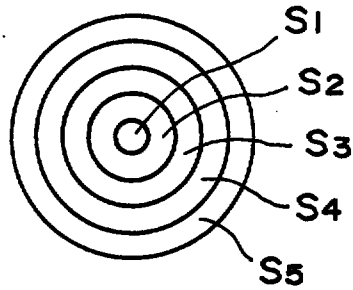


FIG. 2



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FIG. 3A

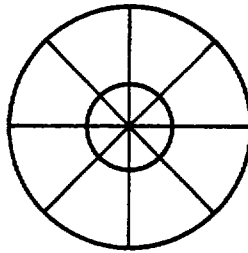


FIG. 3B

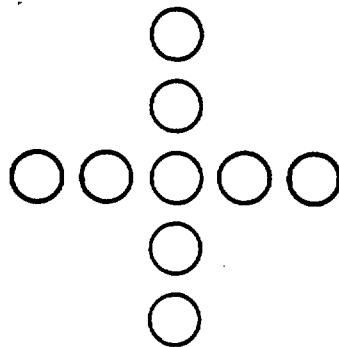


FIG. 3C

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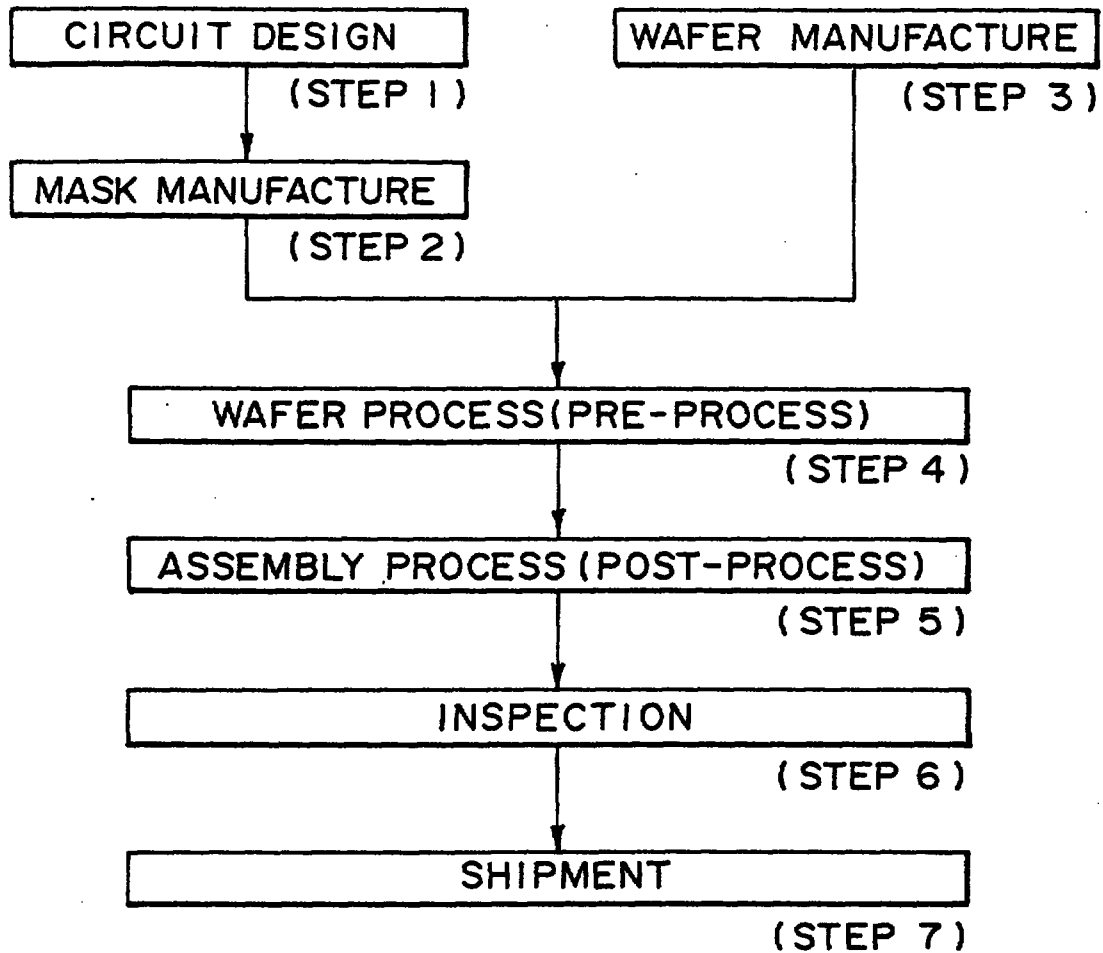


FIG. 4

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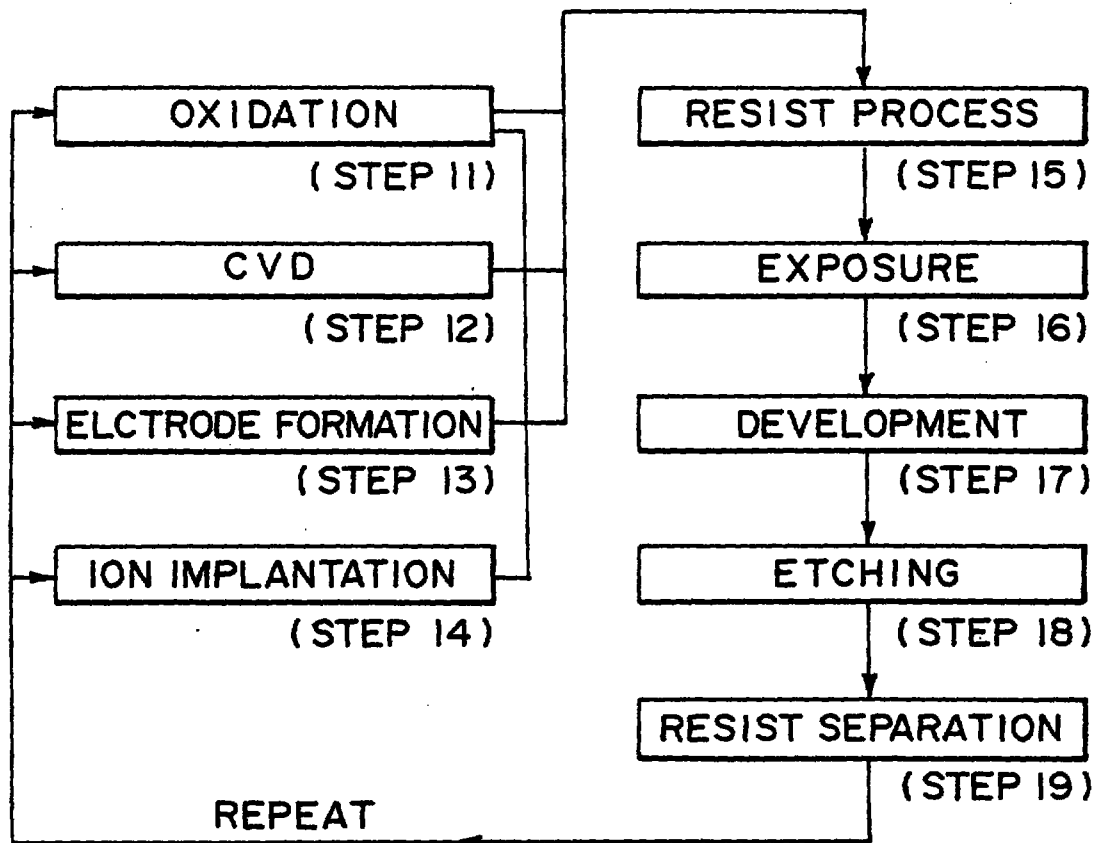


FIG. 5

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PROJECTION EXPOSURE APPARATUS AND DEVICE
MANUFACTURING METHOD USING THE SAME

ABSTRACT OF THE DISCLOSURE

A projection exposure apparatus including a projection optical system for projecting a pattern of a reticle onto a substrate, an optical characteristic detecting device for detecting a change in optical characteristic of the projection optical system, which change may results from the projection of the reticle pattern onto the substrate through the projection optical system, and a light detecting device for detecting at least one of (i) an intensity distribution of light from the reticle pattern, at a position adjacent to the reticle or adjacent to an imaging plane on which the reticle is to be imaged, and (ii) an intensity distribution of the light from the reticle pattern, at a position adjacent to a pupil plane of the projection optical system, wherein the optical characteristic detecting device is arranged to detect the amount of change in optical characteristic in accordance with the intensity distribution detected by the light detecting device.

Figure 1

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REPLACEMENT SHEETS		SG
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☐	Drawing(s) : paged to paged	
☐	Abstract : paged to paged	
DATE OF RECEIPT		25 SEP 1997

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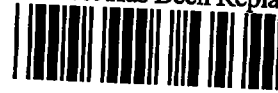
REPLACED SHEETS		SG
☐	Description : paged to paged	
☒	Claim(s) : paged 24 to paged 27	
☐	Drawing(s) : paged to paged	
☐	Abstract : paged to paged	

CLAIMS

1. A projection exposure apparatus, comprising:
 - a projection optical system for projecting a pattern of a reticle on to a substrate;
 - optical characteristic detecting means for detecting a change in optical characteristic of said projection optical system due to the projection of the reticle pattern on to the substrate through said projection optical system; and
 - light detecting means for detecting an intensity distribution of the light from the reticle pattern as defined on a pupil plane of said projection optical system;
 - wherein said optical characteristic detecting means detect the amount of change in optical characteristic in accordance with the intensity distribution detected by said light detecting means.
2. An apparatus according to claim 1, wherein said light detecting means detects an intensity distribution on the reticle.
3. An apparatus according to claim 1, wherein said optical characteristic detecting means detects at least one of (i) the amount of change of an imaging plane of said projection optical system and (ii) the amount of change of projection magnification of said projection optical system.
4. An apparatus according to claim 2, wherein said light detecting means comprises first light detector means having a light detecting surface disposed at the imaging plane of said projection optical system, for detecting the light intensity distribution on the reticle, and second light detector means having a light detecting surface disposed at a position away from the imaging plane of said projection optical system, for detecting the light intensity distribution on the pupil plane of said projection optical system.

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5. An apparatus according to claim 2, wherein said light detecting means comprises a light blocking plate with a pinhole disposed at the imaging plane, and a plurality of photoelectric converting elements arrayed at a position away from the imaging plane, for detecting light passing through the reticle pattern, through said projection optical system and through the pinhole of said light blocking plane, wherein the light intensity distribution on the pupil plane of said projection optical system is determined on the basis of output distribution of said photoelectric converting elements, wherein the light intensity on the reticle is determined by using the sum of outputs of said photoelectric converting elements, and wherein said light blocking plate and said photoelectric converting elements are movable as a unit along the imaging plane.

6. A projection exposure apparatus, comprising:

a projection optical system for projecting a pattern of a reticle on to a substrate;

optical characteristic detecting means for detecting a change in optical characteristic of said projection optical system due to the projection of the reticle pattern on to the substrate through said projection optical system;

light detecting means for detecting an intensity distribution of the light from the reticle pattern as defined on a pupil plane of said projection optical system;

wherein said optical characteristic detecting means detect the amount of change in optical characteristic in accordance with the intensity distribution detected by said light detecting means; and

optical characteristic correcting means for substantially correcting the change in optical characteristic of said projection optical system in accordance with an output of said optical characteristic detecting means.

7. An apparatus according to claim 6, wherein said light detecting means detects an intensity distribution on the reticle.





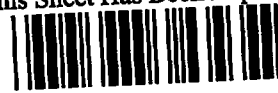
8. An apparatus according to claim 6, wherein said optical characteristic detecting means detects at least one of (i) the amount of change of an imaging plane of said projection optical system and (ii) the amount of change of projection magnification of said projection optical system.

9. An apparatus according to claim 7, wherein said light detecting means comprises first light detector means having a light detecting surface disposed at the imaging plane of said projection optical system, for detecting the light intensity distribution on the reticle, and second light detector means having a light detecting surface disposed at a position away from the imaging plane of said projection optical system, for detecting the light intensity distribution on the pupil plane of said projection optical system.

10. An apparatus according to claim 7, wherein said light detecting means comprises a light blocking plate with a pinhole disposed at the imaging plane, and a plurality of photoelectric converting elements arrayed at a position away from the imaging plane, for detecting light passing through the reticle pattern, through said projection optical system and through the pinhole of said light blocking plane, wherein the light intensity distribution on the pupil plane of said projection optical system is determined on the basis of output distribution of said photoelectric converting elements, wherein the light intensity on the reticle is determined by using the sum of outputs of said photoelectric converting elements, and wherein said light blocking plate and said photoelectric converting elements are movable as a unit along the imaging plane.

11. An apparatus according to claim 8, wherein said optical characteristic correcting means performs one of (i) moving the reticle and said projection optical system along an optical axis direction and (ii) moving the substrate along the optical axis direction to thereby correct the change of the imaging plane and to register the surface of the substrate and the imaging plane.





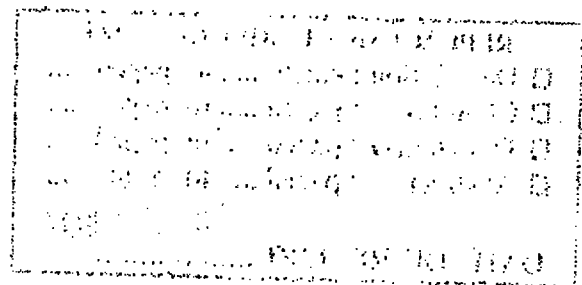
12. An apparatus according to claim 8, wherein said optical characteristic correcting means changes a focal distance of said projection optical system to correct the change of the imaging plane and to register the surface of the substrate and the imaging plane.

13. An apparatus according to claim 8, wherein said optical characteristic correcting means moves one of the reticle and a lens of said projection optical system along an optical axis direction to correct the change of the projection magnification.

14. An apparatus according to claim 8, wherein said optical characteristic correcting means changes a focal distance of said projection optical system to correct the change in the projection magnification.

15. A device manufacturing method for manufacturing a device such as an integrated circuit, a large scale integrated circuit, a liquid crystal device or a magnetic head, said method comprising:

printing a device pattern on a substrate by use of a mask that includes the device pattern and a projection exposure apparatus as recited in any one of claims 1 - 14.





WHAT IS CLAIMED IS:

1. A projection exposure apparatus, comprising an illumination system (1) for illuminating a reticle (2); a projection optical system (4) for projecting a pattern of the reticle on to a substrate; and optical characteristic detecting means (21, 22, 23, 24) for detecting a change in optical characteristic of said projection optical system due to the projection of the reticle pattern on to the substrate through said projection optical system, characterized in that:

said optical characteristic detecting means includes light detecting means (21, 22, 23) for detecting an intensity distribution of the light from the reticle pattern, which distribution is defined on the pupil plane (13) of said projection optical system, wherein said optical characteristic detecting means detects the amount of change in optical characteristic in accordance with the intensity distribution detected by said light detecting means.

2. An apparatus according to claim 1, wherein said light detecting means detects an intensity distribution on the reticle.
3. An apparatus according to claim 1, wherein said optical characteristic detecting means detects at least one of (i) the amount of change of an imaging plane of said projection optical system and (ii) the amount of change of projection magnification of said projection optical system.

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Date: 22 MAY 1998

5. An apparatus according to claim 2, wherein said light detecting means comprises a light blocking plate with a pinhole disposed at the imaging plane, and a plurality of photoelectric converting elements arrayed at a position away from the imaging plane, for detecting light passing through the reticle pattern, through said projection optical system and through the pinhole of said light blocking plane, wherein the light intensity distribution on the pupil plane of said projection optical system is determined on the basis of output distribution of said photoelectric converting elements, wherein the light intensity on the reticle is determined by using the sum of outputs of said photoelectric converting elements, and wherein said light blocking plate and said photoelectric converting elements are movable as a unit along the imaging plane.

6. A projection exposure apparatus, comprising an illumination system (1) for illuminating a reticle (2); a projection optical system (4) for projecting a pattern of the reticle on to a substrate; optical characteristic detecting means (21, 22, 23, 24) for detecting a change in optical characteristic of said



Date: 22 MAY 1998



projection optical system due to the projection of the reticle pattern on to the substrate through said projection optical system; and optical characteristic correcting means for substantially correcting the change in optical characteristic of said projection optical system in accordance with an output of said optical characteristic detecting means, characterized in that:

said optical characteristic detecting means includes light detecting means (21, 22, 23) for detecting an intensity distribution of the light from the reticle pattern, which distribution is defined on the pupil plane (13) of said projection optical system, wherein said optical characteristic detecting means detects the amount of change in optical characteristic in accordance with the intensity distribution detected by said light detecting means.

7. An apparatus according to claim 6, wherein said light detecting means detects an intensity distribution on the reticle.

8. An apparatus according to claim 6, wherein said optical characteristic detecting means detects at least one of (i) the amount of change of an imaging plane of said projection optical system and (ii) the amount of change of projection magnification of said projection optical system.

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Date: 22 MAY 1998



9. An apparatus according to claim 7, wherein said light detecting means comprises first light detector means having a light detecting surface disposed at the imaging plane of said projection optical system, for detecting the light intensity distribution on the reticle, and second light detector means having a light detecting surface disposed at a position away from the imaging plane of said projection optical system, for detecting the light intensity distribution on the pupil plane of said projection optical system.

10. An apparatus according to claim 7, wherein said light detecting means comprises a light blocking plate with a pinhole disposed at the imaging plane, and a plurality of photoelectric converting elements arrayed at a position away from the imaging plane, for detecting light passing through the reticle pattern, through said projection optical system and through the pinhole of said light blocking plane, wherein the light intensity distribution on the pupil plane of said projection optical system is determined on the basis of output distribution of said photoelectric converting elements, wherein the light intensity on the reticle is determined by using the sum of outputs of said photoelectric converting elements, and wherein said light blocking plate and said photoelectric converting elements are movable as a unit along the imaging plane.

11. An apparatus according to claim 8, wherein said optical characteristic correcting means performs one of (i) moving the reticle and said projection optical system along an optical axis direction and (ii) moving the substrate along the optical axis direction to thereby correct the change of the imaging plane and to register the surface of the substrate and the imaging plane.

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Date: 22 MAY 1998



12. An apparatus according to claim 8, wherein said optical characteristic correcting means changes a focal distance of said projection optical system to correct the change of the imaging plane and to register the surface of the substrate and the imaging plane.

13. An apparatus according to claim 8, wherein said optical characteristic correcting means moves one of the reticle and a lens of said projection optical system along an optical axis direction to correct the change of the projection magnification.

14. An apparatus according to claim 8, wherein said optical characteristic correcting means changes a focal distance of said projection optical system to correct the change in the projection magnification.

15. A device manufacturing method for manufacturing a device such as an integrated circuit, a large scale integrated circuit, a liquid crystal panel, a CCD, or a magnetic head, said method comprising:

printing a device pattern on a substrate by use of a mask that includes the device pattern and a projection exposure apparatus as recited in any one of Claims 1 - 14.

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22 MAY 1998



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Date: 09 JUN 1998

WHAT IS CLAIMED IS:

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☒ Claim(s)	: paged 24 to paged 28	
☐ Drawing(s)	: paged to paged	
☐ Abstract	: paged to paged	
DATE OF RECEIPT		9 JUN 1998

1. A projection exposure apparatus, comprising an illumination system (1) for illuminating a reticle (2); a projection optical system (4) for projecting a pattern of the reticle on to a substrate; and optical characteristic detecting means (21, 22, 23, 24) for detecting a change in optical characteristic of said projection optical system due to the projection of the reticle pattern on to the substrate through said projection optical system, characterized in that:

said optical characteristic detecting means includes light detecting means (21, 22, 23) for detecting an intensity distribution of the light from the reticle pattern, which distribution is defined on the pupil plane (13) of said projection optical system, wherein said optical characteristic detecting means detects the amount of change in optical characteristic in accordance with the intensity distribution detected by said light detecting means.

2. An apparatus according to claim 1, wherein said light detecting means detects an intensity distribution on the reticle.

3. An apparatus according to claim 1, wherein said optical characteristic detecting means detects at least one of (i) the amount of change of an imaging plane of said projection optical system and (ii) the amount of change of projection magnification of said projection optical system.



Date: 09 JUN 1998

4. An apparatus according to claim 2, wherein said light detecting means comprises first light detector means having a light detecting surface disposed at the imaging plane of said projection optical system, for detecting the light intensity distribution on the reticle, and second light detector means having a light detecting surface disposed at a position away from the imaging plane of said projection optical system, for detecting the light intensity distribution on the pupil plane of said projection optical system.

5. An apparatus according to claim 2, wherein said light detecting means comprises a light blocking plate with a pinhole disposed at the imaging plane, and a plurality of photoelectric converting elements arrayed at a position away from the imaging plane, for detecting light passing through the reticle pattern, through said projection optical system and through the pinhole of said light blocking plane, wherein the light intensity distribution on the pupil plane of said projection optical system is determined on the basis of output distribution of said photoelectric converting elements, wherein the light intensity on the reticle is determined by using the sum of outputs of said photoelectric converting elements, and wherein said light blocking plate and said photoelectric converting elements are movable as a unit along the imaging plane.

6. A projection exposure apparatus, comprising
an illumination system (1) for illuminating a reticle
(2); a projection optical system (4) for projecting a
pattern of the reticle on to a substrate; optical
characteristic detecting means (21, 22, 23, 24) for
detecting a change in optical characteristic of said



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- 26 -

Date: 09 JUN 1998

projection optical system due to the projection of the reticle pattern on to the substrate through said projection optical system; and optical characteristic correcting means for substantially correcting the change in optical characteristic of said projection optical system in accordance with an output of said optical characteristic detecting means, characterized in that:

said optical characteristic detecting means includes light detecting means (21, 22, 23) for detecting an intensity distribution of the light from the reticle pattern, which distribution is defined on the pupil plane (13) of said projection optical system, wherein said optical characteristic detecting means detects the amount of change in optical characteristic in accordance with the intensity distribution detected by said light detecting means.

7. An apparatus according to claim 6, wherein said light detecting means detects an intensity distribution on the reticle.

8. An apparatus according to claim 6, wherein said optical characteristic detecting means detects at least one of (i) the amount of change of an imaging plane of said projection optical system and (ii) the amount of change of projection magnification of said projection optical system.



Date: 09 JUN 1998

9. An apparatus according to claim 7, wherein said light detecting means comprises first light detector means having a light detecting surface disposed at the imaging plane of said projection optical system, for detecting the light intensity distribution on the reticle, and second light detector means having a light detecting surface disposed at a position away from the imaging plane of said projection optical system, for detecting the light intensity distribution on the pupil plane of said projection optical system.

10. An apparatus according to claim 7, wherein said light detecting means comprises a light blocking plate with a pinhole disposed at the imaging plane, and a plurality of photoelectric converting elements arrayed at a position away from the imaging plane, for detecting light passing through the reticle pattern, through said projection optical system and through the pinhole of said light blocking plane, wherein the light intensity distribution on the pupil plane of said projection optical system is determined on the basis of output distribution of said photoelectric converting elements, wherein the light intensity on the reticle is determined by using the sum of outputs of said photoelectric converting elements, and wherein said light blocking plate and said photoelectric converting elements are movable as a unit along the imaging plane.

11. An apparatus according to claim 8, wherein said optical characteristic correcting means performs one of (i) moving the reticle and said projection optical system along an optical axis direction and (ii) moving the substrate along the optical axis direction to thereby correct the change of the imaging plane and to register the surface of the substrate and the imaging plane.



Date: 09 JUN 1998

12. An apparatus according to claim 8, wherein said optical characteristic correcting means changes a focal distance of said projection optical system to correct the change of the imaging plane and to register the surface of the substrate and the imaging plane.

13. An apparatus according to claim 8, wherein said optical characteristic correcting means moves one of the reticle and a lens of said projection optical system along an optical axis direction to correct the change of the projection magnification.

14. An apparatus according to claim 8, wherein said optical characteristic correcting means changes a focal distance of said projection optical system to correct the change in the projection magnification.

15. A device manufacturing method for manufacturing a device such as an integrated circuit, a large scale integrated circuit, a liquid crystal panel, a CCD, or a magnetic head, said method comprising:

printing a device pattern on a substrate by use of a mask that includes the device pattern and a projection exposure apparatus as recited in any one of Claims 1 - 14.

