

Description

FIELD OF THE INVENTION AND RELATED ART

This invention relates to an exposure apparatus and, more particularly, to an exposure apparatus suitably usable in the manufacture of semiconductor microcircuit devices, for printing through a projection optical system a pattern formed on a reticle (mask) upon a photoresist layer on the surface of a semiconductor wafer.

Usually, such an exposure apparatus is provided with an alignment function because of the necessity of superimposingly printing different patterns of various reticles upon the same semiconductor wafer. There are two types of alignment systems: one is a TTL (through-the-lens) alignment system wherein alignment marks of a reticle and/or a wafer are observed through a projection optical system to obtain alignment information; whereas the other is an off-axis alignment system wherein the alignment information is obtained by observing one or more alignment marks formed on a wafer by use of an observation optical system, such as a microscope, which is provided at a position spaced away from the optical axis of a projection optical system.

While the TTL alignment system has an advantage of better alignment accuracy, there is a necessity of correcting, by suitable means, optical aberrations caused by the projection optical system in an occasion where the observation of alignment marks is made by use of a light of a wavelength different from that used for the pattern printing. In this case, therefore, a complicated structure is required. Where the pattern printing wavelength is used also for the observation, there are caused different problems. One is that the photoresist material applied to the wafer is sensitized at the time of the mark observation. Another problem is that, when a resist structure such as a multi-layered resist structure having good light absorbing property (efficiently absorbing the light of the pattern printing wavelength) is used, only an insufficient quantity of light is reflected from the wafer at the time of the mark observation. In the off-axis alignment system, on the other hand, light of a wavelength different from the pattern printing wavelength may be used for the mark observation without any specific inconvenience. Also, the required structure is simple. However, there may be easily caused a problem in respect to the alignment accuracy.

Reference is made to US-A-4414749 which discloses a step-and-repeat alignment and exposure system.

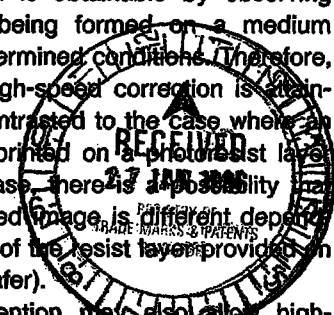
It is an object of the present invention to provide an improved exposure apparatus which en-

ables errors within the system to be detected using light of a wavelength different from a pattern printing wavelength. A further object is to assure high-precision alignment by means of a simple arrangement.

According to the invention there is provided an apparatus comprising a movable stage for holding thereon a substrate; an illumination system for illuminating a pattern of an original with an exposure light having a predetermined wavelength; and a projection optical system for projecting the pattern of the original, illuminated by said light on the substrate; characterised by recording means including a recording medium mounted on said stage at a position off set from said substrate serving to record an image of a mark of the the original projected through said projection optical system in response to illumination of the mark with light of substantially the same wavelength as that of the exposure light, said recording medium including an erasable and rewritable recording material provided on said movable stage; and a mark detecting device for photoelectrically detecting the image of the mark as recorded on said recording medium, independently of said projection optical system, whereby an error within said exposure apparatus can be detected on the basis of information produced through the detection of the image of the mark by said mark detecting device.

Where it is desired, for example, to conduct "base line correction" for correcting data concerning the interval between optical axes of a projection optical system and an off-axis observation optical system the aforesaid recording medium may be exposed through the projection optical system so that an image of a mark of the first object may be "printed" on the recording medium. Thereafter, the movable stage may be displaced, with the amount of displacement thereof being measured by suitable means, so that the "printed" image of the mark may be located under the observation optical system and observed thereby. With this procedure, alignment information is obtainable by observing such an image as being formed on a medium maintained under determined conditions. Therefore, high-precision and high-speed correction is obtainable. This is quite contrasted to the case where an image of a mark is printed on a photoresist layer since, in the latter case, there is a possibility that the state of the formed image is different depending on the conditions of the resist layer provided on the second object (wafer).

The present invention may also allow high-precision correction of a magnification error and/or a focus error. It is known that such a magnification error or a focus error is not constant but is variable. As for the magnification error, it varies with the expansion/contraction of a second object (wafer)



due to the processes thereof such as an etching process, a diffusion process or otherwise or, alternatively, with the change in the environment conditions of a projection optical system such as an ambient temperature, an ambient pressure or otherwise. Also, the focus error is variable with the change in the environment conditions. Particularly, with regard to the depth of focus of a projection optical system, there are the following relations:

$$W = K_1 \cdot \lambda / NA$$

$$d = K_2 \cdot \lambda / (NA)^2$$

wherein W is the linewidth of a printed pattern, λ is the wavelength of light used for the pattern printing, NA is the numerical aperture, d is the depth of focus and K_1 and K_2 are constants. It is seen therefrom that, if a shorter wavelength λ or a larger numerical aperture NA is used for narrowing the linewidth W , the depth of focus of a projection optical system is reduced in proportion to the shortening of the wavelength or in proportion to the square of the increment of the numerical aperture. Accordingly, the narrower the linewidth of the printed pattern is, the larger the effect of the focus shift is. Further, in an exposure apparatus of the type wherein an excimer laser whose spectral bandwidth is narrowed is used as a light source, any change in the emission wavelength of the excimer laser will cause a change in the magnification or in the focus position.

Accordingly, it is another object of the present invention to provide an exposure apparatus by which high-precision real-time correction of any magnification error and/or focus error is attainable.

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

Figure 1 is a schematic view showing a general structure of an exposure apparatus according to one embodiment of the present invention.

Figures 2A - 2C are schematic views, respectively, explicating the action made in the neighborhood of a magneto-optic recording medium used in the apparatus of Figure 1.

Figure 3 is a flow chart showing the manner of the alignment operation made in the apparatus of Figure 1.

Figure 4 is a schematic view of an exposure apparatus according to another embodiment of the present invention.

Figure 5 is a flow chart showing the manner of operation made in the apparatus of Figure 4.

Figure 6 is a schematic view showing a general structure of an exposure apparatus according to a further embodiment of the present invention.

Figures 7A and 7B are schematic views, respectively, showing the action made in the neighborhood of a photochromic glass plate used in the apparatus of Figure 6.

Figure 8 is a flow chart showing the manner of the alignment operation made in the apparatus of Figure 6.

Figure 9 is a schematic view of an exposure apparatus according to yet another embodiment of the present invention.

Figure 10 is a flow chart showing the manner of operation made in the apparatus of Figure 9.

Figure 11 is a schematic and diagrammatic view, exemplifying a systematic structure of an exposure apparatus according to the present invention.

Figure 12 is a schematic and diagrammatic view, showing a systematic structure of an exposure apparatus according to a still further embodiment of the present invention.

Figure 13 is an enlarged view showing details of a reticle used in the apparatus of Figure 2.

Figures 14A - 14C are schematic views, respectively, explicating the action made in the neighborhood of a magneto-optic recording medium used in the apparatus of Figure 12.

Figure 15 is a flow chart showing the manner of the magnification and/or focus detecting operation made in the apparatus of Figure 12.

Figure 16 is a schematic and diagrammatic view, showing a systematic structure of an exposure apparatus according to a yet further embodiment of the present invention.

Figure 17 is a flow chart showing the manner of the focusing operation made in the apparatus of Figure 16.

Figure 18 is a schematic view showing a major portion of an exposure apparatus according to a still further embodiment of the present invention.

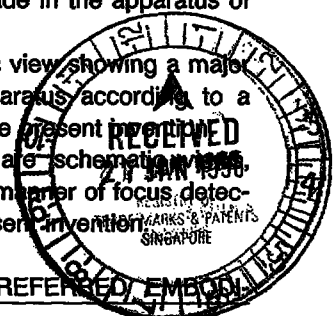
Figures 19A and 19B are schematic views, respectively, explicating the manner of focus detection in one aspect of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the attached drawings, embodiments of the present invention will be described.

Figure 1 shows a general structure of a step-and-repeat type exposure apparatus according to one embodiment of the present invention.

In Figure 1, light emanating from an illumination optical system 1 irradiates a reticle 2 so that a



pattern formed thereon is transferred through a projection optical system 3 onto one of different portions (shot areas) of a wafer 4. The wafer 4 is held on a movable stage 5 which is movably disposed on a surface plate 10 for stepwise movement for the step-and-repeat exposures of the wafer 4.

The movable stage 5 is adapted to be moved in X and Y directions by means of driving systems, not shown, and the displacement (the amount of movement) of the stage is monitored by use of X-axis and Y-axis laser interferometric gauges. In Figure 1, only the X-axis laser interferometric gauge is illustrated at reference numeral 8 and the Y-axis laser interferometric gauge is not shown. Each laser interferometric gauge 8 emits a laser beam along an optical axis whose height (in a Z-axis direction) is the same as the height of the wafer 4 surface for preclusion of an Abbe's error.

Provided on the movable stage 5 and outside the wafer 4 is a magneto-optic recording medium 6 which is disposed so that the height of the surface thereof is coincident with the height of the wafer 4. Further, as required, there may be provided an adjusting mechanism which is effective to bring the height of the surface of the magneto-optic recording medium 6 and the height of the wafer 4 into exact coincidence with each other. Provided below the magneto-optic recording medium 6 is an electromagnet 7 which is embedded in the movable stage so as to apply a magnetic field in the direction of the optical axis of the projection optical system 3, i.e. along the Z-axis.

Alignment optical system 9 comprises, for example, a lamp 14 adapted to emit a light of a wavelength with respect to which a resist material applied to the wafer 4 is substantially insensitive; an optical-path dividing beam splitter 15; an objective lens 16; and an observation TV camera 17. The pictorial image as obtained by the TV camera 17 is transmitted to a computer, not shown, and is processed therein such that the position detection is carried out.

Another illumination optical system 11 is provided to illuminate an alignment mark 18 formed on the reticle. This optical system 11 functions to extract a portion of the photoprinting light of the illumination optical system 1 to irradiate a slit member 12 and also functions to form an image of a slit aperture of the slit member 12 upon the reticle 2 surface. The introduction of the light beam from the illumination optical system 1 to the mark illuminating optical system 11 is "ON/OFF" controlled by means of a shutter 13.

Taking in conjunction with Figures 2A - 2C schematically illustrating the action made in the neighborhood of the magneto-optic recording medium 6, description will now be made in accor-

dance with the flow chart of Figure 3 to the manner of monitoring the distance between the optical axes of the projection optical system 3 and the alignment optical system 9 included in the apparatus of Figure 1.

The situation is that, such as illustrated in Figure 1, a reticle 2 has been set at a predetermined position (Step 101) and a wafer 4 has been placed on the movable stage 5 (Step 102). The following operations are made under the situation described.

a) Figure 2A

First, at Step 103, the medium 6 is preparatorily magnetized downward. At Step 104, the movable stage 5 is displaced so as to locate the medium 6 at a position which is just underneath the projection optical system 3 and on which the alignment mark 18 of the reticle 2 is going to be imaged. Subsequently, at Step 105, the shutter 13 opens so that the alignment mark 18 on the reticle is exposed to the light from the mark irradiating optical system 11. As a result, an image of the mark 18 is formed on the medium 6. In such occasion, the electromagnet 7 may be preparatorily actuated to apply an upward magnetic field. Thus, only such portion of the medium 6 on which the light impinges can absorb the light and the temperature of that portion increases to the Curie point due to the heat caused thereby, with the result that the direction of magnetization is reversed.

In this manner, there is formed in the medium 6 a reversely magnetized portion of a shape corresponding to that of the alignment mark 18. The resolution of the medium 6 is determined by the magnitude of the domain and is about 0.02 micron in this example which is sufficient for the purpose of the present embodiment. Further, use of a ultraviolet light which is usually used for the semiconductor exposure purpose is effective because usually a magneto-optic medium 6 shows a high absorption factor and the photon energy itself is high.

After the exposure of the mark 18 is completed, the shutter 13 is closed.

b) Figure 2B

Subsequently, at Step 106, the movable stage 5 is displaced through a vector "b" which is substantially the same as the vector extending from the position of the mark 18 exposure by the projection optical system 3 to the optical axis of the alignment optical system 9, so as to locate the medium 6 at a position substantially right under the objective lens 16 of the alignment optical system 9. The displacement "b" in the X and Y directions during such movement is precisely measured by



the laser interferometric gauges 8. At that position, the alignment mark now formed on the medium 6 (as a result of Step 105 described hereinbefore) is observed and, on the basis of the difference in the state of polarization resulting from the difference in the direction of magnetization, any error or deviation " α " of the position of the mark on the medium 6 with respect to a certain reference position (which may be determined by a reference mark formed in the alignment optical system 9) is detected. From the displacement of the stage 5 having been measured by the laser interferometric gauges 8 and the detected error " α " of the mark position as well as by using the data concerning the distance between the mark 18 and the optical axis of the projection optical system 3, it is possible to accurately detect the distance between the optical axes of the projection optical system 3 and the alignment optical system 9.

For the subsequent step-and-repeat exposures which start with Step 108, the movable stage is moved so as to locate an alignment mark of a predetermined shot area on the wafer 4 under the alignment optical system 9. Thereafter, by use of this optical system 9, any positional error ϵ of that alignment mark of the wafer 4 with respect to the reference position defined in the optical system 9 is measured. Thereafter, by an amount corresponding to the sum of the error ϵ and the distance between the optical axes detected in the previous Step, the movable stage 5 is displaced in accordance with the output of the laser interferometric gauge 8, whereby the aforesaid predetermined shot area is aligned with respect to the exposure position. Alternatively, the data concerning the positional error ϵ is corrected by use of the previously detected error " α " so as to exclude, out of the error ϵ , the component which results from the error in the distance between the optical axes of the optical systems 3 and 9. By doing so, correct data for the subsequent alignment operation can be obtained.

In this example, desired one of a die-by-die alignment procedure (Steps 109 - 114) and a global alignment procedure (Steps 115 - 123) can be selected at Step 108 and the exposures can be made accordingly. In the case of the die-by-die alignment procedure, the positional error of each shot area on the wafer 4 is measured such that every shot area on the wafer is aligned on the basis of the positional error data peculiar thereto. In the case of the global alignment procedure, on the other hand, some shot areas (sample shot areas) on the wafer are elected and, from the measured values concerning the positions of alignment marks of these shot areas and from the coordinate positions of the stage 5 at the time of the measurements of the mark positions, a reference grid re-

presenting the array of the shot areas on the wafer 4 is prepared by calculation, the thus prepared reference grid being used subsequently to control the step-and-repeat movement of the stage 5 to thereby control the alignment of all the shot areas of the wafer.

c) Figure 2C

When, as the movable stage 5 is at an arbitrary position, the electromagnet 7 is actuated to apply an intense downward magnetic field, the whole of the medium 6 is magnetized downwardly so that the mark is erased. Thus, the medium 6 is prepared for reuse. This is made at Step 124 after the completion of the step-and-repeat exposures.

The present invention is not limited to the form of the above-described embodiment, but may be modified conveniently.

For example:

I) The erasing of the mark at Step 124 may be conducted just before the mark exposure at Step 105. Further, at the time of erasing, the whole surface of the medium 6 may be irradiated with light. By doing so, the mark can be erased only with a magnetic field of an intensity similarly to that of the magnetic field applied at the time of the mark exposure, without use of an intense magnetic field.

II) The electromagnet 7 may be replaced by a permanent magnet which can be inverted upside-down. Also, with regard to the position thereof, it may be disposed at any of various positions other than the position right under the medium 6. In short, the magnetic field applying means may be of any structure and may be disposed at any position, provided that it can apply, to the medium 6 and after the exposure, a desired upward or downward magnetic field along the optical axis of the projection optical system 3.

III) Depending on the material used for the magneto-optic recording medium 6, there is a limitation to the number of serviceable cycles. Also, there is a possibility of changes with aging. In consideration of these points, including the medium 6 may be preferably formed into a unit part, which can facilitate the replacement, for example.

IV) The irradiation of an alignment mark by a reticle may be made without use of the mark irradiating optical system 11. For example, as shown in Figure 4, the alignment mark can be irradiated by directly using the illumination optical system 1. In such a case, the whole surface of a reticle 2 may be illuminated. However, depending on the environmental conditions, it is possible that a formed magneto-optic image

changes due to the heat, resulting in deterioration of the precision. In order to prevent this, a masking mechanism such as at 19 may be provided within the illumination optical system 1 so as to assure that, with this masking mechanism 19, only an alignment mark of the reticle 2 is illuminated at the time of the printing of the mark on the medium 6 for the formation of a magneto-optic image of the mark. An example of the operational sequence in such a case is illustrated in the flow chart of Figure 5. In this example, the masking and the removal thereof are carried out at Steps 203 and 206 before and after the mark exposure at Step 205.

V) As described hereinbefore, the detection of the image of the alignment mark 18, formed on the medium 6, is based on the detection of the difference in the state of polarization. Accordingly, it is very effective to construct the alignment optical system 9 so that it can be used as a polarization microscope.

VI) The mark irradiating optical system 11 may be used for the positioning of a reticle.

VII) In an occasion where the light source in the illumination optical system 1, used for the pattern printing, comprises an "ON/OFF" controllable light source means such as a laser, the shutter 13 may be omitted.

VIII) As for the light source for irradiating the mark 18, it is not always necessary to extract a portion of the photoprinting light from the illumination optical system 1. A separate light source which produces a light of substantially the same wavelength may be used.

Next, another embodiment of the present invention will be described with reference to Figure 6. In the embodiment which will be described just below, a photochromic material is used as the recording medium.

In Figure 6, light emanating from an illumination optical system 1 irradiates a reticle 2 so that a pattern formed thereon is transferred through a projection optical system 3 onto one of different portions (shot areas) of a wafer 4. The wafer 4 is held on a movable stage 5 which is movably disposed on a surface plate 10 for stepwise movement for the step-and-repeat exposures of the wafer 4.

The movable stage 5 is adapted to be moved in X and Y directions by means of driving systems, not shown, and the displacement (the amount of movement) of the stage is monitored by use of X-axis and Y-axis laser interferometric gauges. In Figure 6, only the X-axis laser interferometric gauge is illustrated at reference numeral 8 and the Y-axis laser interferometric gauge is not shown. Each laser interferometric gauge 8 has an optical axis whose height (in a Z-axis direction) is the

same as the height of the wafer 4 surface for preclusion of an Abbe's error.

Provided on the movable stage 5 and outside the wafer 4 is a photochromic glass plate 60 which is disposed so that the height of the surface thereof is coincident with the height of the wafer 4. Further, as required, there may be provided an adjusting mechanism which is effective to bring the height of the surface of the photochromic glass plate 60 and the height of the wafer 4 into exact coincidence with each other.

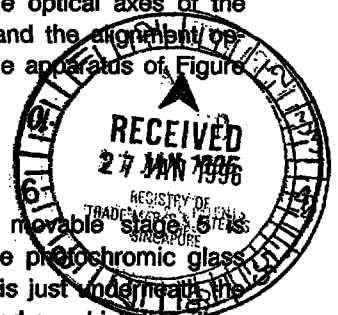
Alignment optical system 9 comprises, for example, a lamp 14 adapted to emit a light of a wavelength with respect to which a resist material applied to the wafer 4 is substantially insensitive; an optical-path dividing beam splitter 15; an objective lens 16; and an observation TV camera 17. The pictorial image as obtained by the TV camera 17 is transmitted to a computer, not shown, and is processed therein such that the position detection is carried out.

Another illumination optical system 11 is provided to illuminate an alignment mark 18 formed on the reticle. This optical system 11 functions to extract a portion of the photoprinting light of the illumination optical system 1 to irradiate a slit member 12 and also functions to form an image of a slit aperture of the slit member 12 upon the reticle 2 surface. The introduction of the light beam from the illumination optical system 1 to the mark illuminating optical system 11 is "ON/OFF" controlled by means of a shutter 13.

Taking in conjunction with Figures 7A and 7B schematically illustrating the action made in the neighborhood of the photochromic glass plate 60, description will now be made in accordance with the flow chart of Figure 8 to the manner of monitoring the distance between the optical axes of the projection optical system 3 and the alignment optical system 9 included in the apparatus of Figure 6.

a) Figure 7A

First, at Step 303, the movable stage 5 is displaced so as to locate the photochromic glass plate 60 at a position which is just underneath the projection optical system 3 and on which the alignment mark 18 of the reticle 2 is going to be imaged. The reticle 2 has been held immovable at a predetermined position, relatively to the projection optical system 3. Subsequently, at Step 304, the shutter 13 opens so that the alignment mark 18 on the reticle is exposed to the light from the mark irradiating optical system 11. As a result, the mark 18 is imaged on the photochromic glass plate 60. At this time, since the photochromic glass plate 60 has such characteristics that only such a portion as



being irradiated with light (particularly, ultraviolet light) is colored due to the photochemical action, an image of the mark 18 is formed on this glass plate 60. Usually, the ultraviolet light usable for the semiconductor exposure purpose has a large photon energy as compared with that of an ordinary visible light, a sharp image of the mark can be formed with certainty. After the exposure of the mark 18 is completed, the shutter 13 is closed.

b) Figure 7B

Subsequently, at Step 305, the movable stage 5 is displaced through a vector "b" which is substantially the same as the vector extending from the position of the mark 18 exposure by the projection optical system 3 to the optical axis of the alignment optical system 9, so as to locate the photochromic glass plate 60 at a position substantially right under the objective lens 16 of the alignment optical system 9. The displacement "b" in the X and Y directions during such movement is precisely measured by the laser interferometric gauges 8. At that position, the alignment mark now formed on the glass plate 60 (as a result of Step 304 described hereinbefore) is observed by use of the TV camera 17.

At this time, it is desirable to use, as the observation light, a faint light or such a light of a long wavelength having a small photon energy in order to prevent that the photochromic glass plate 60 is colored by the observation light.

From the displacement of the stage 5 having been measured by the laser interferometric gauges 8 and the detected error "a" of the mark position, it is possible to accurately detect the distance between the optical axes of the projection optical system 3 and the alignment optical system 9.

Thereafter, as in the embodiment described before, a desired one of a die-by-die alignment procedure (Steps 308 - 313) and a global alignment procedure (Steps 314 - 323) can be selected at Step 307, and the exposures can be made accordingly.

It should be noted here that the mark image formed on the photochromic glass plate 60 is spontaneously erased with the lapse of a certain time after completion of the light irradiation, so that the photochromic glass plate can be used again.

The above-described embodiment can be modified conveniently, such as follows:

i) There is a possibility that the photochromic glass plate 60 is colored by the irradiation with light, other than the photoprinting light, such as an external illumination light, for example. In consideration thereof, it is desirable to protect the photochromic glass plate 60 to prevent, as much as possible, the photochromic glass plate

60 from being irradiated with unwanted light, by use of a suitable means such as a filter having specific characteristics that only the wavelength or wavelengths of the photoprinting light and the alignment observation light are transmitted, whereas light of other wavelengths is intercepted.

ii) Usually, a photochromic glass plate has such characteristics that the speed of coloring and decoloring becomes higher with a lower temperature. For this reason, it is desirable to provide the stage 5 with a cooling mechanism such as at 70 in Figure 9, for cooling a photochromic glass plate 60. With this mechanism, the photochromic glass plate may be cooled during the above-described mark exposure so as to increase the mark printing speed. Also, the photochromic glass plate may be cooled after completion of the measurement of the mark position so as to increase the mark erasing speed. By doing so, a further reduction of the alignment time is attainable, with the result that the throughput can be increased accordingly. Further, a heating mechanism for heating a photochromic glass plate 60 may be provided, so as to heat the glass plate during the mark observation. By doing so, it is possible to prevent the coloring of the photochromic glass plate 60 by the irradiation with the mark observation light. This can be attained by, for example, annexing a heating function to the above-described cooling mechanism 70 so that the same can operate as a heating/cooling mechanism.

iii) Depending on the material of a photochromic glass used or the time interval between successive cycles of the sequential operation according to the present invention, there is a possibility that the mark formed on the photochromic glass plate is not completely erased before the subsequent mark exposure. In such an occasion, each time the image of the mark may be formed at a slightly shifted position upon the same photochromic glass plate. Assuming that a photochromic glass plate used has a size of 11 centimeter square while the mark observation field of the alignment optical system 9 has a size of 700 micron square, there are ten thousands mark printing positions, which is sufficient for this purpose.

iv) The irradiation of an alignment mark on a reticle may be made without use of the mark irradiating optical system 11. For example, the illumination optical system 1 may be directly used for this purpose, such as shown in Figure 9. In such an occasion, the whole surface of a reticle may be illuminated. However, as in the case described in paragraph iii) or otherwise, it

may be desired to selectively irradiate, with light, only such portion of the reticle 2 close to the alignment mark thereof. If this is desired, a masking mechanism 19 may be provided within the illumination optical system 1, such that only a portion of the reticle 2 is selectively exposed to form an image of the mark. Figure 10 shows an example of the sequential monitoring operation in an occasion where a masking mechanism such as described above as well as a cooling/heating mechanism such as described in paragraph ii) are provided, namely in the case of the Figure 9 structure. In the illustrated example, the cooling is conducted at the time of the mark exposure (Step 405) and the mark erasing (Step 425), while the heating is effected at the time of measurement (Step 407). The remaining portion is essentially the same as that of the foregoing embodiment.

Figure 11 is a block diagram showing a general structure of an exposure apparatus which is capable of executing each of the sequences of the flow charts having been described with reference to the foregoing embodiments.

In Figure 11, same reference numerals as of the foregoing embodiments are assigned to corresponding elements, so that description of these elements is omitted here for simplicity.

Denoted at 20 is a reticle stage for supporting a reticle 2. The reticle stage is movable in each of X, Y and Z directions and in a θ (rotational) direction about the Z-axis. Denoted at 22 is a reticle stage driving means for driving the reticle stage 20 in each of X, Y, Z and θ directions. Denoted at 52 is a driving means for driving a wafer stage 5 in each of X, Y, Z and θ directions.

Control means 90 is operable to control the alignment operation and the exposure operation, for example, to be made in the exposure apparatus of the present embodiment. Input/output means 91 is operable to apply to the control means 90 various instructions concerning the alignment or exposure conditions. Also, the input/output means operates so that specific information such as positional error information, for example, is displayed in a CRT or outputted by a printer or otherwise.

By means of signal lines as illustrated, an illumination optical system 1, a mark irradiating optical system 11, laser interferometric gauges 8, the reticle stage driving means 22, the wafer stage driving means 52, an alignment optical system 9 and an electromagnet 7 (or a heating/cooling mechanism 70) are coupled to the control means 90. Accordingly, by way of these signal lines, predetermined control signals from the control means 90 can be transmitted to the aforesaid mechanism, optical systems and driving means.

The manner of measuring the distance (reference length) between the optical axes of a projection optical system 3 and the alignment optical system 9, is substantially the same as that described hereinbefore.

The correct reference length as obtained by the measurement made in the described manner is stored into a memory (not shown) of the controller 90, and the stored data is used later as a reference value for the movement of a wafer stage 5, at the time of the positioning of a wafer (or each shot area on the wafer) to be made successfully.

Figure 12 is a schematic view showing a general structure of a step-and-repeat type exposure apparatus according to a further embodiment of the present invention. In Figure 12, light emanating from an illumination optical system 1 irradiates a reticle 2 which is a first object, so that a pattern formed thereon is transferred through a reduction projection optical system 3 onto a wafer 4 which is a second object. The wafer 4 is held on a movable stage 5 which is disposed on a surface plate 10.

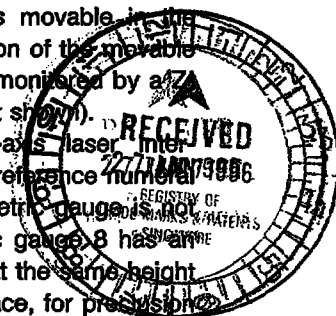
The projection optical system 3 is supported by a barrel (not shown) and is provided with a lens driving means (also not shown) so that, as will be described later, predetermined one or ones of plural lens elements, constituting the projection optical system 3, can be displaced as desired.

The reticle 2 is held on a reticle stage (not shown) which is adapted to be moved by a reticle driving means 92 in each of X, Y, Z and θ directions.

The movable stage 5 is adapted to be moved in X and Y directions by means of a driving system 93, and the displacement (the amount of movement) of the stage is monitored by means of X-axis and Y-axis laser interferometric gauges such as at 8. Also, the movable stage 5 is movable in the direction of Z-axis, and the position of the movable stage 5 in the Z-axis direction is monitored by a Z-axis position detecting means (not shown).

In Figure 12, only the X-axis laser interferometric gauge is illustrated at reference numeral 8 and the Y-axis laser interferometric gauge is not shown. Each laser interferometric gauge 8 has an optical axis which is maintained at the same height as the height of the wafer 4 surface, for prevention of an Abbe's error.

Provided on the movable stage 5 and outside the wafer 4 is a magneto-optic recording medium 6 which is disposed so that the height of the surface thereof is substantially coincident with the height of the wafer 4. Further, as required, there may be provided an adjusting mechanism which is effective to bring the height of the surface of the magneto-optic recording medium 6 and the height of the wafer 4 into exact coincidence with each other. Provided below the magneto-optic recording me-



dium 6 is an electromagnet 7 (magnetic field applying means) which is embedded in the movable stage so as to apply a magnetic field in the direction of the optical axis of the projection optical system 3, i.e. along the Z-axis.

Additionally, in order to prevent the magnetic field, produced by the electromagnet 7, from adversely affecting other components, a magnetic shield member 22 is provided to surround the electromagnet. This shield member 22 is also effective to preclude that a magnetic field is applied from said other components to the magneto-optic recording medium 6.

Observation optical system 9 is provided at a position spaced from the optical axis of the projection optical system 3 and is disposed in parallel to the optical axis of the projection optical system. The observation optical system 9 comprises, for example, a lamp 14, an optical-path dividing beam splitter 15, an objective lens 16 and an observation TV camera 17. Additionally, the observation optical system may include a polarization microscope. The pictorial image as obtained by the TV camera 17 is transmitted to a computer 90 and is processed therein, such that the position detection and the contrast detection are carried out.

There are provided mark irradiating optical systems 11a and 11b for irradiating focus/magnification detecting marks 18a and 18b, respectively, which are formed on the reticle 2. Each of the mark irradiating optical systems 11a and 11b functions to extract a portion of the photoprinting light of the illumination optical system 1 to irradiate corresponding one of slit members 12a and 12b, and also functions to form an image of a slit aperture of the corresponding slit member 12a or 12b upon the reticle 2 surface. The introduction of the light from the illumination optical system 1 to each of the mark irradiating optical systems 11a and 11b is "ON/OFF" controlled by means of corresponding one of shutters 13a and 13b.

As best seen in Figure 13, the two marks 18a and 18b are formed on the reticle 2 surface and at those positions outside a region 22, in which a circuit pattern is provided, and inside an effective projection field 21 as determined by the projection optical system 3. These two marks are spaced by a distance L. Denoted at 20a and 20b in Figure 13 are the ranges of irradiation by the mark irradiating optical systems 11a and 11b, respectively.

Figures 14A - 14C schematically illustrate the action made in the neighborhood of the magneto-optic recording medium 6 of the Figure 12 embodiment. The manner of detection of the magnification and focus of the projection optical system 3, in the apparatus of the Figure 12 embodiment, will now be described in conjunction with Figures 14A - 14C

as well as the flow chart of Figure 15. In Figures 14A - 14C, the illustration of the magnetic shield member 22 is omitted for simplicity.

5 a) Figure 14A

First, at Step 503, the medium 6 is preparatorily magnetized downward. At Step 504, the movable stage 5 is displaced so as to locate the medium 6 at a position which is just underneath the projection optical system 3 and on which the alignment marks 18a and 18b of the reticle 2 are going to be imaged. Subsequently, at Step 505, the shutter 13a (13b) opens so that the alignment mark 18a (18b) on the reticle is exposed to the light from the mark irradiating optical system 11a (11b). As a result, an image of the mark 18a (18b) is formed on the medium 16. In such occasion, the electromagnet 7 may be preparatorily actuated to apply an upward magnetic field. Thus, only such portion of the medium 6 on which the light impinges can absorb the light and the temperature of that portion increases to the Curie point due to the heat caused thereby, with the result that the direction of magnetization is reversed.

In this manner, there are formed in the medium 6 two reversely magnetized portions (left-hand and right-hand portions) each having a shape corresponding to that of the alignment mark 18a or 18b. The resolution of the medium 6 is determined by the magnitude of the domain and is about 0.02 micron in this example which is sufficient for the purpose of the present embodiment. Further, use of a ultraviolet light which is usually used for the semiconductor exposure purpose is effective because usually a magneto-optic medium 6 shows a high absorption factor and the photon energy itself is high.

After the exposure of the mark 18a (18b) is completed, the shutter 13a (13b) is closed.

b) Figure 14B

Subsequently, at Step 506, the movable stage 5 is displaced through a vector "b" which is substantially the same as the vector extending from the position of the mark 18a (18b) exposure by the projection optical system 3 to the optical axis of the observation optical system 9, so as to locate the medium 6 at a position substantially right under the objective lens 16 of the observation optical system.

At that position, the magnetization images of the left-hand and right-hand marks, having been formed on the medium 6 as a result of step 506, are observed by use of the observation optical system 9. At this time, due to the difference in the state of polarization of light from the medium 6, which difference results from the difference in the

magnetization, images of the marks are formed upon the TV camera 17. Therefore, the interval l between the left-hand and right-hand marks can be measured. For this measurement, the stage is displaced so as to locate one of the marks at a position substantially right under the optical axis of the observation optical system 9 and, thereafter, a positional error α_1 is measured. Subsequently, the stage is displaced substantially through an amount l_0 so as to locate the other mark at a position substantially right under the optical axis of the observation optical system 9 and, thereafter, a positional error α_2 is measured. The second-time displacement " l_0 " of the stage is measured by means of the laser interferometric gauge 8. All the results of measurements are supplied to the computer 90 by way of respective signal lines, not shown. The interval l between the two marks at that time can be expressed by:

$$l = |l_0 + \alpha_1 - \alpha_2|$$

On the other hand, the magnification β of the projection optical system 3 can be given by:

$$\beta = 1/L$$

Where such a magnification that can be treated as a reference is denoted by β_0 , then the magnification error $\Delta\beta$ is expressed as follows:

$$\Delta\beta = \beta - \beta_0$$

These calculations are made by the computer 90 and, in the present embodiment, the magnification error $\Delta\beta$ is corrected by upwardly or downwardly displacing the reticle 2 by use of the reticle driving means 92 or, alternatively, by displacing one or ones of the lens elements of the projection optical system 3 by use of the lens driving means, not shown.

As for the focus control, the focus is detected by detecting the linewidth of the magnetization image of the mark, having been formed on the medium 6. The correspondence or interrelationship between the linewidth and the focus position may be based on a defocus versus linewidth curve which may be preparatorily stored in a processing unit (not shown) of the computer 90. Since the linewidth is variable with the amount of exposure, in the present embodiment the amount of exposure at the time of transfer of a mark 18a (18b) onto the medium, made at Step 505, is maintained constant. In order to correct the thus detected focus error, the wafer 4 is displaced upwardly or downwardly by the wafer stage driving means 93. Alternatively, one or more of the lens elements of the projection optical system 3 may be displaced for this purpose

by use of the lens driving means, not shown. These operations are made at Steps 507 - 511.

c) Figure 14C

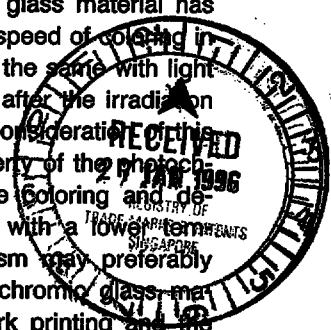
When, as the movable stage 5 is at an arbitrary position, the electromagnet 7 is actuated to apply an intense magnetic field downwardly to the medium 6, the whole of the medium 6 is magnetized downward so that the marks are erased. Thus, the medium 6 is prepared for reuse.

The present invention in this aspect is not limited to the form of the embodiment described just above, but may be modified conveniently in various ways. Examples are as follows:

(1.1) As for an erasably writable recording medium, a photochromic glass material which is sensitized by a light such as a ultraviolet light and is colored thereby, may be used. Further, any one of many varieties of recording media on which information (pattern) is erasably writable by use of light or radiation may be used. An example of such recording medium is an amorphous recording material in which a phase change between crystallization and uncrystallization occurs as a result of a temperature change.

Where such a recording medium described just above is used, there is no necessity of a magnetic field as required in the case of a magneto-optic recording medium used in the foregoing embodiment. Therefore, it is not necessary to use an electromagnet. Additionally, there is no necessity of providing a polarization microscope within the observation optical system.

Usually, a photochromic glass material has such characteristics that the speed of coloring in response to the irradiation of the same with light and the speed of decoloring after the irradiation is discontinued, are low. In consideration of this and by utilizing such a property of the photochromic glass material that the coloring and decoloring speed is increased with a lower temperature, a cooling mechanism may preferably be added to cool the photochromic glass material at the time of the mark printing and the mark erasing. If, nevertheless, the speed is not sufficiently high, a plurality of different positions may be defined on a photochromic glass plate, for the formation of images of the focus/magnification detecting marks, so that each time an image of a mark is formed at a different position. After a sufficient time period lapses and mark images formed at an initial stage are erased, mark images may be formed again at the initial mark image forming positions.



Further, depending on the material of a photochromic glass used, there is a possibility that the photochromic glass material is sensitized not only by the photoprinting light but also by the observation light or any external light. In consideration of this, it may be desirable to add a heating mechanism for heating the photochromic glass material, contrary to the foregoing case, so as to retain, as much as possible, the state of the photochromic glass material for a time period after the mark exposure to the mark erasing (particularly, during the observation). Since a super-precision machine such as a stepper (step-and-repeat type exposure apparatus) is very sensitive to the temperature change, it is desirable, where such a cooling and/or heating mechanism is added, to use a suitable heat insulating means to isolate the cooling/heating mechanism so that the temperature change is not transmitted to surrounding components.

The modification described just above is attainable in the Figure 12 embodiment by replacing the medium 6 by a photochromic glass plate; by replacing the electromagnet 7 by a heating/cooling device; and by forming the member 22 by a heat insulating material.

(1.2) Rather than providing an observation optical system at a position spaced from the optical axis of the projection optical system and in parallel to the optical axis of the projection optical system, as described in the foregoing, the optical arrangement may be modified so that a mark is observed from the above of the projection optical system and by way of the projection optical system. In such a case, the projection optical system and the observation optical system may have a common optical axis. Accordingly, there is an advantage of that the necessity of moving the stage for displacing the medium from the position under the projection optical system to the position under the observation optical system, can be omitted. However, usually a projection optical system is aberration-corrected only with respect to the photoprinting wavelength. Accordingly, there arise limitations such as, for example, that the observation should be made by use of the photoprinting wavelength or that chromatic aberration should be corrected.

(1.3) The observation optical system may be used also as an alignment optical system, only by a minute modification such as that a reference mark is provided within the observation optical system and any error between the observed mark and the reference mark is measured. In this case, where the observation optical system is provided at a position spaced

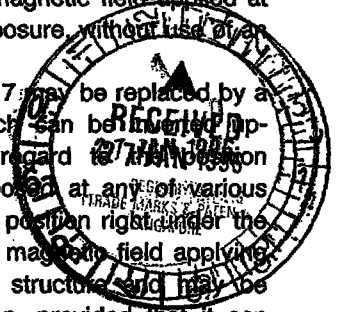
from the optical axis of the projection optical system and is disposed in parallel to that optical axis, as in the Figure 12 embodiment, the observation optical system can function as an "off-axis" alignment optical system. If, on the other hand, the observation optical system is disposed above the projection optical system as in the case described in paragraph (1.2), the observation optical system can function as a "TTL" (through-the-lens) alignment optical system.

In any case, desired one of a die-by-die alignment procedure and a global alignment procedure can be selected and the exposures can be made accordingly. In the case of the die-by-die alignment procedure, the positional error of each shot area on a wafer is measured such that every shot area on the wafer is aligned on the basis of the positional error data peculiar thereto. In the case of the global alignment procedure, on the other hand, some shot areas (sample shot areas) on the wafer are elected and, from the measured values concerning the positions of alignment marks of these shot areas and from the coordinate positions of the wafer stage at the time of the measurements of the mark positions, a reference grid is prepared by calculation, the thus prepared reference grid being used subsequently to control the step-and-repeat movement of the stage to thereby control the alignment of all the shot areas of the wafer.

(1.4) The erasing of the mark at Step 512 may be conducted just before the mark exposure at Step 505. Further, at the time of erasing, the whole surface of the medium 6 may be irradiated with light. By doing so, the mark can be erased only with a magnetic field of an intensity similarly to that of the magnetic field applied at the time of the mark exposure, without use of an intense magnetic field.

(1.5) The electromagnet 7 may be replaced by a permanent magnet which can be oriented upside-down. Also, with regard to the disposition thereof, it may be disposed at any of various positions other than the position right under the medium 6. In short, the magnetic field applying means may be of any structure and may be disposed at any position, provided that it can apply to the medium 6 and after the exposure a desired upward or downward magnetic field along the optical axis of the projection optical system 3.

(1.6) Depending on the material used for the magneto-optic recording medium 6, there is a limitation to the number of serviceable cycles. Also, there is a possibility of changes with aging. In consideration of them, the portion including the medium 6 may be preferably formed into a unit part, which can facilitate the replace-



ment, for example.

(1.7) The irradiation of an alignment mark on a reticle may be made without use of the mark irradiating optical system 11a (11b). That is, the alignment mark may be irradiated by directly using the illumination optical system 1. In such a case, the whole surface of a reticle 2 may be illuminated. However, depending on the environmental conditions, it is possible that a formed mark image changes due to the heat. In order to prevent this, a masking mechanism may be provided within the illumination optical system 1 so as to assure that, with this masking mechanism, only a portion of the reticle 2 is illuminated to form an image of the mark.

(1.8) The mark irradiating optical system 11a (11b) may be used for the positioning of a reticle.

(1.9) In an occasion where the light source in the illumination optical system 1, used for the pattern printing, comprises an "ON/OFF" controllable light source means such as a laser, the shutter 13a (13b) may be omitted.

(1.10) As for the light source for irradiating the mark 18, it is not always necessary to extract a portion of the photoprinting light from the illumination optical system 1. A separate light source which produces a light of substantially the same wavelength may be used.

(1.11) Since the magnification of a projection optical system does not always change rectilinearly within the field of projection of the projection optical system, two or more pairs of magnification detecting marks may be provided so as to allow that the magnification is calculated by use of a least square method.

(1.12) Where a photochromic glass is used as the medium 6, the focus detection may be made on the basis of detection of the contrast of the mark image.

(1.13) The observation optical system 9 may be used to measure errors or deviations γ_1 and γ_2 in the direction perpendicular to a straight line connecting two images formed on the medium 6. By doing so, it becomes possible to detect the deviation of a reticle in the plane thereof (which is called "reticle rotation"), in terms of the following equation:

$$\theta = (\gamma_1 - \gamma_2)/l$$

For the correction of such an error, either a reticle or a wafer may be placed on a rotatable stage so that one of the reticle and wafer may be rotated in the plane thereof.

(1.14) At the time of measurement of the interval l between two marks for the detection of the magnification, the two marks may be observed

simultaneously. This eliminates the necessity of the stage movement and, therefore, is effective to assure high-speed measurement.

Figure 16 is a schematic view showing a general structure of a step-and-repeat type projection exposure apparatus according to a yet another embodiment of the present invention.

In Figure 16, light emanating from an illumination optical system 1 irradiates a reticle 2 which is a first object so that a pattern formed thereon is transferred through a projection optical system 3 onto a wafer 4 which is second object. The wafer 4 is coated with a resist material (photo-sensitive material) held on a movable stage 5 which is movably disposed on a surface plate 10.

The movable stage 5 is adapted to be moved in X and Y directions as well as in a Z direction (along the optical axis of the projection optical system 3) by means of driving systems, not shown, and the displacement (the amount of movement) of the stage is monitored by use of X-axis, Y-axis and Z-axis laser interferometric gauges. In Figure 1, only the X-axis laser interferometric gauge is illustrated at reference numeral 8 and the Y-axis and Z-axis laser interferometric gauges are not shown. Each laser interferometric gauge 8 has an optical axis whose height is the same as the height of the wafer 4 surface for preclusion of an Abbe's error.

Denoted at 30 is an integration type exposure meter. Signals from the integration type exposure meter 30, representing exposures (exposure amounts) at successive time moments, are applied in sequence to a controller 90. If the attainment of a predetermined exposure amount is discriminated, a shutter of the illumination optical system 1 is closed in response to a signal from the controller 90, whereby the exposure is stopped.

If, at the time of transfer of a focus detecting pattern onto the resist layer, the amount of exposure (irradiating the pattern) changes, the state of the transferred pattern will change with the change in the exposure amount even where the pattern has been projected in an in-focus state. Accordingly, it becomes quite difficult to correctly discriminate the in-focus state or to correctly detect the amount of defocus. In the present embodiment, in consideration of this, it is important to accurately control the amount of exposure by use of the exposure meter 30.

Denoted at 19 is a masking mechanism provided within the illumination optical system 1. At the time of ordinary exposure (photoprinting of a circuit pattern), the masking mechanism is retracted. When a focus detecting pattern 18 formed on the reticle 2 surface is going to be projected upon a certain region on the wafer 5 so as to form an image of the pattern 18 on that region of the resist surface on the wafer 4, the masking mechanism is

introduced to allow that only a portion of the reticle 2 surface close to the focus detecting pattern 18 is illuminated.

The masking member of the masking mechanism may be located, at this time, just above or below the reticle 2.

Observation system 9 is provided to observe an undeveloped image of the focus detecting pattern 18 (which image is a latent image of the pattern 18), having been formed on the resist layer on the wafer 4 surface.

As described with reference to the preceding embodiment, the inventors of the subject application have found the capability of focus control on the basis of detecting the line width, for example, of a magneto-optically formed image, formed on a magneto-optic recording medium with the aid of an imaging or projection optical system. Basically, the present embodiment has started with the preceding embodiment and, thus, is an advanced form of the preceding embodiment, particularly in the point that the necessity of use of a specific magneto-optic recording material in the preceding embodiment is omitted. Namely, in the present embodiment, the focus control is made on the basis of detecting the state of an image, being photochemically formed with the aid of the imaging or projection optical system upon an ordinary resist layer which is quite usually provided on a wafer. Thus, in the present embodiment, the focus is controlled by using a latent image of a reticle pattern, which latent image per se is known in the art as disclosed in Japanese Laid-Open Patent Application, Lai-Open No. Sho61-114529.

Turning back to Figure 16, the observation system 9 includes a light source 14 which produces light of a wavelength or wavelengths with respect to which the resist material of the wafer 4 is not sensitive. The light source 14 is imaged by means of a lens 29 at a position close to the pupil of an objective lens 16. The light emanating from the light source 14 goes by way of the lens 29, a half mirror 15 and the objective lens 16 to irradiate the wafer 4 surface. The light reflected from such region of the wafer 4 surface as being illuminated is received by the objective lens 16 and the received light is directed by way of the half mirror 15 to a TV camera 17, whereby the wafer 4 surface is observed. The operation of the present embodiment will be described in greater detail with reference to the flow chart of Figure 17.

In order that the focus detecting pattern 18 formed on the reticle 2 is projected upon the wafer 4 surface to form thereon an image of that pattern, first at Step 601 the stage 5 is displaced by a stage driving means 93 so as to locate the pattern image forming position on the wafer 4 surface, at the location right under the projection optical sys-

tem 3.

Then, at Step 602, the controller 90 controls the masking mechanism 19 so as to introduce the masking member of the mechanism into the path for the illumination light, such that the focus detecting pattern 18 is selectively irradiated with light from the illumination optical system 1 (Step 603). As a result, an image of the focus detecting pattern 18 is formed on the resist layer on the wafer 4 surface with the aid of the projection optical system 3. Subsequently, the wafer stage 5 is displaced again by the stage driving means 93 so as to locate the pattern image (which is an undeveloped image) at the position right under the observation system 9. The state of image-formation of the undeveloped pattern image at that time is observed by use of the TV camera 17 (Step 605).

The undeveloped pattern image picked-up by the TV camera 17 is processed by a computer (not shown) of the controller 90 (Step 606), and the amount of deviation δ of the focus with respect to a correct focus position is detected (Step 607), on the basis of, for example, the contrast of the pattern image or the size of the pattern image in comparison to the size of the original pattern. Within the computer of the controller 90, predetermined conversion equations concerning the interrelationship between the focus error δ and the contrast or size of the pattern image have been preparatorily stored. Thus, from the contrast, for example, as can be calculated from the pictorial image related to the undeveloped pattern image, the amount of deviation δ of the focus position can be determined.

Subsequently, at Step 608, as an example the wafer 4 is displaced vertically along the Z-axis and in the direction effective to correct the focus error δ so that the wafer 4 surface coincides with the focus position. Thereafter, at Step 609, the masking member is retracted and the projection exposure of the circuit pattern formed on the reticle 2 surface is initiated.

It is an alternative form of the present embodiment that the wafer stage driving means 93 is modified to move the wafer 4 stepwise along a vertical direction at predetermined regular increments (pitches) and, simultaneously therewith, to move the stage 5 horizontally and that, while moving the wafer 4 and stage 5 in the described manner, images of the focus detecting pattern 18 are formed at different positions on the wafer 4 surface. If this is adopted, the highest contrast position at which the pattern image has the maximum contrast, namely the best focus position, can be determined on the basis of the interpolation with respect to the contrast values of the pattern images corresponding to the different positions of the wafer 4 surface in the vertical direction, this being attainable without storing in the computer the conversion



equations concerning the relation "contrast of the pattern image versus focus error".

Particularly, where a pulsed laser such as an excimer laser in which the pulse emission time (duration) is very short, is used as a light source, it is possible to form images of the focus detecting pattern 18 upon the wafer with continuous movement of the stage 5, namely without repeatedly stopping the stage 5 at the respective positions for the formation of those images of the focus detecting pattern. Thus, the throughput can be improved significantly.

In the present embodiment, an undeveloped image of the focus detecting pattern 18 may be utilized, for example, for the alignment of the reticle 2 and the wafer 4 or the detection of the magnification of the projection optical system 3. This may be made by use of the observation optical system 9 simultaneously with the focus detection.

The adjustment of the focus position is not limited to the vertical displacement of the wafer 4. For example, the focus adjustment is attainable by vertically displacing the wafer 2; by displacing the projection optical system 3 and some of the components thereof; or by changing the environmental conditions of the projection optical system 3.

Further, a variable-wavelength laser such as a band narrowed excimer laser may be used as a light source, such that the focus position can be adjusted by changing the wavelength by adjusting, for example, the angle of a mirror or etalon which is included as a part of a band-narrowing device.

The above-described embodiment uses a latent image forming process, according to which an image of a focus detecting pattern 18 is formed on a resist layer on a wafer 4 surface.

An embodiment of the present invention which will be described below uses a method which is contrasted to the latent image forming process. More specifically, in place of forming a latent image on a resist material, an optical writable/erasable recording medium such as, for example, a magneto-optic recording medium or a photochromic material is used.

Figure 18 is a fragmentary structural view showing a still further embodiment of the present invention, and shows an observation system 9' as well as the portion of the Figure 16 apparatus which includes a wafer stage 5.

Denoted in Figure 18 at 6 is a magneto-optic recording medium and, at 7 is a magnetic field producing means, comprising an electromagnet, for example, for applying to the recording surface of the medium 6 a perpendicular biasing magnetic field. As compared with the observation system 9 of the Figure 16 embodiment, the observation system 9' of the present embodiment is provided by a polarization microscope. In Figure 18, same refer-

ence numerals as of the Figure 16 embodiment are assigned to corresponding elements, and description thereof is omitted here for simplicity.

Also in the present embodiment shown in Figure 18, the wafer stage 5 is adapted to be moved precisely in each of X, Y and Z directions by a stage driving means in accordance with control signal from a controller. Further, the wafer stage 5 is arranged to be rotationally moved about the Z-axis.

In the present embodiment, an image of a focus detecting pattern is formed on the magneto-optic recording medium 6. In this case, the magneto-optic recording medium 6 is disposed so that the recording surface of the medium 6 has substantially the same height as of the surface of the resist layer on the wafer 4.

In the portion of the magneto-optic recording medium 6 in which the image of the focus detecting pattern is formed, the direction of perpendicular magnetization is reversed due to the photothermoeffect. This means that a pattern corresponding to the state of focus of the formed image is recorded on the magneto-optic recording medium 6.

On the other hand, the magneto-optic recording medium 6 on which such a pattern has been recorded is thereafter subjected to the observation by the observation optical system 9' which comprises a polarization microscope, whereby the state of the recorded pattern is observed. More specifically, there is a difference between (i) the direction of polarization of a linearly polarized light reflected, as a result of the illumination of the medium 6, back from such portion of the medium which corresponds to the pattern and in which the magnetization has been reversed and (ii) the direction of polarization of a linearly polarized light reflected from the portion of the medium in which the magnetization has not been reversed. Accordingly, by observing the recording medium by selectively extracting the reflected light from the pattern by use of an analyzer or otherwise, the state of the pattern recorded on the recording medium, namely the degree of blur of the pattern and/or the size thereof, can be detected.

Since the sequential operation for the above-described observation is similar to that described with reference to the Figure 16 embodiment, the explanation thereof is omitted here for simplicity.

After the focus detection is completed, a magnetic field of a predetermined intensity is applied by a magnetic field producing means 7 to the magneto-optic recording medium in a direction perpendicular to the recording surface of the recording medium. By this, the state of magnetization of such portion in which the reverse of magnetization has been caused can be returned to its initial state, such that the magneto-optic recording medium is

prepared for reuse.

Use of an erasably writable optical recording medium in the manner described above provides a specific advantage that the focus can be detected repeatedly by use of one and the same recording medium, this being a significant contradistinction to the latent image forming method wherein an undesirable latent image is formed on a resist layer.

As for such an erasably writable optical recording medium usable in the present invention, there are many varieties of optical recording mediums, other than a magneto-optic recording medium. For example, a photochromic material described hereinbefore, an amorphous material wherein the phase is changeable between crystallization and uncrystallization, etc. are usable.

Where a photochromic material is used as a recording medium, the element denoted at 6 in Figure 18 will be made of a photochromic material and, in such case, the element denoted at 7 may preferably be provided by a cooling means. Since usually a photochromic material has such characteristics that the speed of coloring and decoloring increases with lower temperature, it is easily possible to controllably increase or decrease, as desired, the image forming speed for the formation of an image of a focus detecting pattern and/or the image erasing speed for erasing the image of the focus detecting pattern after use, this being attainable by the action of the cooling means 7.

Finally, a convenient method of detecting the focus error on the basis of a pattern formed on a recording medium will be briefly described, taken in conjunction with Figures 19A and 19B. Figure 19A shows the state of concentration of a pattern printing light in a case where the surface of the medium 6 is at an in-focus position of the projection optical system 3. Figure 19B shows the state of concentration of the pattern printing light in a case where the surface of the medium 6 is deviated from the in-focus position by an amount ΔZ .

Assuming that the linewidth of a pattern 18 (see Figure 16 for example) formed on a reticle 2 is NW and the reducing magnification of the projection optical system 3 is $1/N$, then in the Figure 19A case the pattern printing light is concentrated upon the region of the medium 6 surface having a width W . In the Figure 9B case, on the other hand, the light is concentrated upon a region of a width of " $W + \Delta W$ ". Where the F-number of the light is denoted by $F\#$, then there is a relation between ΔW and ΔZ , such as follows:

$$\Delta Z = \Delta W \cdot F\#$$

It will be readily understood from the above that the focus error can be easily detected by detecting the width " $W + \Delta W$ " by use of the ob-

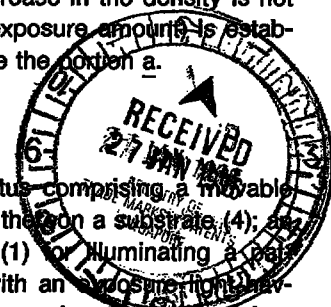
servation optical system 9 (Figure 16).

Usually, in a projection exposure apparatus to which the present invention is applicable, an allowable focus error is of an order of 0.5 - 1 micron and the F-number $F\#$ is not greater than 1.4. Accordingly, the required detection accuracy with regard to the magnitude ΔW is, at the minimum, of an order of 0.35 micron. This numerical value, when it is magnified by use of an observation system having a magnification 40x to a magnitude "14 microns" upon the image pickup surface of a TV camera 17, approximately corresponds to the size of one pixel (picture element) of an ordinary charge coupled device. Thus, it is easily detectable in terms of an image. In other words, the focus error can be very easily detected by using an observation optical system 9 which is capable of magnifying an image, formed on a recording medium 6, at a magnification of about 40x.

It is seen from Figure 19B that the portion of the medium 6 surface denoted at a can be exposed by substantially the same amount of exposure as of the portion of the medium 6 surface of the width W in the Figure 19A example: whereas, in such portion of the region of the width " $W + \Delta W$ " of the Figure 19B example other than the portion a, the exposure amount is reduced remarkably. In consideration of this, it is necessary to control the exposure time so that, in an occasion where the recording medium 6 comprises a magneto-optic recording material, a large amount of exposure sufficient for the reversal of the magnetic field is established at locations outside the portion a. Where the recording medium 6 comprises a photochromic material, it is necessary to control the exposure time so that a saturated exposure amount (i.e. a further increase in the density is not attainable with a larger exposure amount) is established at locations outside the portion a.

Claims

1. An exposure apparatus comprising a movable stage (5) for holding thereon a substrate (4); an illumination system (1) for illuminating a pattern of an original with an exposure light having a predetermined wavelength; and a projection optical system (3) for projecting the pattern of the original, illuminated by said light on the substrate (4); characterised by recording means including a recording medium (6) mounted on said stage at a position off set from said substrate serving to record an image of a mark of the original projected through said projection optical system in response to illumination of the mark with light of substantially the same wavelength as that of the exposure light, said recording medium including an eras-





prepared for reuse.

Use of an erasably writable optical recording medium in the manner described above provides a specific advantage that the focus can be detected repeatedly by use of one and the same recording medium, this being a significant contradistinction to the latent image forming method wherein an undesirable latent image is formed on a resist layer.

As for such an erasably writable optical recording medium usable in the present invention, there are many varieties of optical recording mediums, other than a magneto-optic recording medium. For example, a photochromic material described hereinbefore, an amorphous material wherein the phase is changeable between crystallization and uncrystallization, etc. are usable.

Where a photochromic material is used as a recording medium, the element denoted at 6 in Figure 18 will be made of a photochromic material and, in such case, the element denoted at 7 may preferably be provided by a cooling means. Since usually a photochromic material has such characteristics that the speed of coloring and decoloring increases with lower temperature, it is easily possible to controllably increase or decrease, as desired, the image forming speed for the formation of an image of a focus detecting pattern and/or the image erasing speed for erasing the image of the focus detecting pattern after use, this being attainable by the action of the cooling means 7.

Finally, a convenient method of detecting the focus error on the basis of a pattern formed on a recording medium will be briefly described, taken in conjunction with Figures 19A and 19B. Figure 19A shows the state of concentration of a pattern printing light in a case where the surface of the medium 6 is at an in-focus position of the projection optical system 3. Figure 19B shows the state of concentration of the pattern printing light in a case where the surface of the medium 6 is deviated from the in-focus position by an amount ΔZ .

Assuming that the linewidth of a pattern 18 (see Figure 16 for example) formed on a reticle 2 is NW and the reducing magnification of the projection optical system 3 is $1/N$, then in the Figure 19A case the pattern printing light is concentrated upon the region of the medium 6 surface having a width W . In the Figure 19B case, on the other hand, the light is concentrated upon a region of a width of " $W + \Delta W$ ". Where the F-number of the light is denoted by $F\#$, then there is a relation between ΔW and ΔZ , such as follows:

$$\Delta Z = \Delta W \cdot F\#$$

It will be readily understood from the above that the focus error can be easily detected by detecting the width " $W + \Delta W$ " by use of the ob-

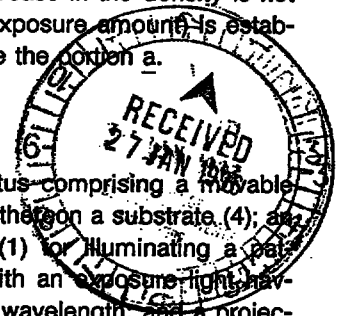
servation optical system 9 (Figure 16).

Usually, in a projection exposure apparatus to which the present invention is applicable, an allowable focus error is of an order of 0.5 - 1 micron and the F-number $F\#$ is not greater than 1.4. Accordingly, the required detection accuracy with regard to the magnitude ΔW is, at the minimum, of an order of 0.35 micron. This numerical value, when it is magnified by use of an observation system having a magnification 40x to a magnitude "14 microns" upon the image pickup surface of a TV camera 17, approximately corresponds to the size of one pixel (picture element) of an ordinary charge coupled device. Thus, it is easily detectable in terms of an image. In other words, the focus error can be very easily detected by using an observation optical system 9 which is capable of magnifying an image, formed on a recording medium 6, at a magnification of about 40x.

It is seen from Figure 19B that the portion of the medium 6 surface denoted at a can be exposed by substantially the same amount of exposure as of the portion of the medium 6 surface of the width W in the Figure 19A example: whereas, in such portion of the region of the width " $W + \Delta W$ " of the Figure 19B example other than the portion a , the exposure amount is reduced remarkably. In consideration of this, it is necessary to control the exposure time so that, in an occasion where the recording medium 6 comprises a magneto-optic recording material, a large amount of exposure sufficient for the reversal of the magnetic field is established at locations outside the portion a . Where the recording medium 6 comprises a photochromic material, it is necessary to control the exposure time so that a saturated exposure amount (i.e. a further increase in the density is not attainable with a larger exposure amount) is established at locations outside the portion a .

Claims

1. An exposure apparatus comprising a movable stage (5) for holding thereon a substrate (4); an illumination system (1) for illuminating a pattern of an original with an exposure light having a predetermined wavelength; and a projection optical system (3) for projecting the pattern of the original, illuminated by said light on the substrate (4); characterised by recording means including a recording medium (6) mounted on said stage at a position off set from said substrate serving to record an image of a mark of the original projected through said projection optical system in response to illumination of the mark with light of substantially the same wavelength as that of the exposure light, said recording medium including an eras-





able and rewritable recording material provided on said movable stage; and a mark detecting device (9) for photoelectrically detecting the image of the mark as recorded on said recording medium (6), independently of said projection optical system, whereby an error within said exposure apparatus can be detected on the basis of information produced through the detection of the image of the mark by said mark detecting device.

2. An apparatus as claimed in claim 1, characterised in that said recording medium (6) comprises a magneto-optic recording member.
3. An apparatus as claimed in claim 1, characterised in that said recording medium (6) comprises a photochromic material.
4. An apparatus as claimed in claim 1, 2 or 3 characterised in that said recording medium (6) is detachably mounted to said movable stage.
5. An apparatus according to claim 1, characterised in that said detecting means (9) comprises a polarization microscope.
6. An apparatus as claimed in claim 2, characterised in that said recording means includes a mechanism (7) effective to apply, to said magneto-optic recording medium provided on said movable stage, a magnetic field in a direction parallel to an optical axis of said projection optical system.
7. An apparatus as claimed in claim 6, characterised in that control means (90) are adapted to establish a sequence according to which (i) the mark on the original is exposed to light from said illumination system with the magnetic field being applied to said magneto-optic recording medium by said magnetic field applying mechanism, to form an image of the mark on said magneto-optic recording medium; (ii) thereafter said movable stage is moved to displace said magneto-optic recording medium toward said detecting means through a predetermined amount so that any deviation of the position of the formed image with respect to a reference position is measured by said detecting means; and (iii) subsequently an inverse magnetic field is applied to said magneto-optic recording medium to erase the image.
8. An apparatus as claimed in claim 7, characterised in that the exposure surface of said

magneto-optic recording medium is at the same height as the exposure surface of the substrate.

9. An apparatus as claimed in claim 3, characterised in that said recording means includes a cooling mechanism for cooling said photochromic material.
10. An apparatus as claimed in claim 9, characterised in that said recording means further includes a heating mechanism for heating said photochromic material.
11. An apparatus as claimed in claim 1, characterised in that said recording medium comprises a glass plate made of a photochromic material.
12. An apparatus as claimed in claim 11, characterised in that said recording means includes a heating/cooling device for heating and/or cooling said photochromic glass plate.
13. An apparatus as claimed in claim 12, characterised in that said heating/cooling device includes heat insulating means effective to prevent any temperature change in a portion of said apparatus close to said photochromic glass plate.
14. An apparatus as claimed in claim 6, characterised in that said magnetic field applying mechanism (7) includes a magnetic shield (22) for preventing a magnetic field from being applied to a portion close to said magneto-optic recording medium.
15. An apparatus as claimed in claim 1, characterised in that said recording medium comprises a glass plate made of a photochromic material and said control means is adapted to receive, on said photochromic glass plate, plural images of the mark on the original image.
16. An apparatus as claimed in claim 1, characterised in that control means adapted to control, on the basis of the detection by said detecting means (9), the position of the substrate in a plane perpendicular to the optical axis of said projection optical system (3).
17. An apparatus as claimed in claim 1, characterised in that control means are provided to detect, on the basis of the information concerning the image on said recording medium and detected by said detecting means, any deviation of the original with respect to a direc-





tion contained in a plane perpendicular to the optical axis of said projection optical system.

18. An apparatus as claimed in claim 1, characterised in that control means are adapted to detect the projection magnification of said projection optical system, on the basis of the information concerning the image on said recording medium and detected by said detecting means.

19. An apparatus as claimed in claim 1, characterised in that control means are adapted to detect, on the basis of the information concerning the image on said recording medium and detected by said detecting means, the state of focus established between the original and substrate by said projection optical system.

20. An apparatus as claimed in claim 1, characterised in that control means are adapted to detect any error in the magnification and/or the focus position of said projection optical system, on the basis of the information concerning the image on said recording medium and detected by said detecting means, and said control means being effective to establish a sequence according to which, after the detected error is corrected, said movable stage is moved to locate the substrate at a position under an optical axis of said projection optical system and, subsequently, the pattern of the original is transferred, by exposure, onto the surface of the substrate.

21. An exposure method comprising the steps of mounting an original pattern having a mark formed thereon and a substrate on a movable stage; illuminating the original by use of an illumination optical system to form, by use of a projection optical system, an image of the mark of the original upon an erasably writable recording medium provided on the movable stage at a position offset from the position at which the substrate is held; detecting the image of the mark by use of a detection optical system independently of the intervention of the projection optical system, and detecting an error within said exposure apparatus on the basis of information produced through the detection of the image of the mark by said mark detection optical system.

22. A method as claimed in claim 21, further comprising detecting the state of focus established between the original and the substrate by the projection optical system, on the basis of the information corresponding to the image of the

mark and detected by the detecting optical system.

23. A method as claimed in claim 22, characterised in that images of the mark of the original are formed at different positions on the photosensitive layer or the recording medium provided on the substrate, while changing the state of focus between the original and the substrate.

24. A method as claimed in claim 22, characterised in that pulsed laser is used as a light source of the illumination optical system and in that projection exposures are successively made while successively moving the substrate in a direction of the optical axis of the projection optical system and in a direction perpendicular to the optical axis, so that the images of the mark of the original are printed at different positions on the photosensitive layer or the recording medium provided on the substrate, with each image printed by one pulse from the pulsed laser.

25. A method as claimed in claim 22, characterised in that a variable wavelength laser is used as a light source of the illumination optical system and in that the state of focus between the original and the substrate is adjusted on the basis of the detection of the state of focus and by changing the wavelength emanating from the variable wavelength laser.

26. A method as claimed in any one of claims 21-25, characterised in that the substrate is aligned with the projection optical system using the obtained information, and the wafer is thereafter exposed to the original pattern using the projection optical system.

Patentansprüche

1. Belichtungsanordnung, die einen gegenüber dem Objektträger (5) zum Halten eines Substrates (4) angeordneten Beleuchtungssystem (1) zum Beleuchten eines Musters einer Vorlage mit Beleuchtungslicht mit einer vorbestimmten Wellenlänge und ein optisches Projektionssystem (3) zum Projizieren des mit diesem Licht beleuchteten Musters der Vorlage auf das Substrat (4) aufweist, gekennzeichnet durch eine Aufzeichnungsvorrichtung mit einem an dem Objektträger an einer gegenüber dem Substrat versetzten Stelle angebrachten Aufzeichnungsträger (6) zum Aufzeichnen eines Bildes einer durch das optische Projektionssystem projizierten Markierung der Vorlage auf das Beleuchtete





- der Markierung mit Licht hin, das im wesentlichen die gleiche Wellenlänge hat wie das Belichtungslicht, wobei der Aufzeichnungsträger ein an dem bewegbaren Objektisch angebrachtes löschbares und wiederbeschriftbares Aufzeichnungsmaterial enthält, und eine Markierungsdetektorvorrichtung (9) zum fotoelektrischen Erfassen des auf dem Aufzeichnungsträger (6) aufgezeichneten Bildes der Markierung unabhängig von dem optischen Projektionssystem, wodurch aufgrund der durch das Erfassen des Bildes der Markierung mittels der Markierungsdetektorvorrichtung ein Fehler in der Belichtungsvorrichtung ermittelt werden kann.
2. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß der Aufzeichnungsträger (6) ein Material zur magnetooptischen Aufzeichnung enthält.
 3. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß der Aufzeichnungsträger (6) ein fotochromes Material enthält.
 4. Vorrichtung nach Anspruch 1, 2 oder 3, dadurch gekennzeichnet, daß der Aufzeichnungsträger (6) an dem bewegbaren Objektisch lösbar angebracht ist.
 5. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß die Detektorvorrichtung (9) ein Polarisationsmikroskop enthält.
 6. Vorrichtung nach Anspruch 2, dadurch gekennzeichnet, daß die Aufzeichnungsvorrichtung einen Mechanismus (7) zum Errichten eines Magnetfeldes an dem an dem bewegbaren Objektisch angebrachten Material zur magnetooptischen Aufzeichnung in einer zu der optischen Achse des optischen Projektionssystems parallelen Richtung enthält.
 7. Vorrichtung nach Anspruch 2, dadurch gekennzeichnet, daß eine Steuereinrichtung (90) zum Ausführen einer Ablauffolge ausgelegt ist, gemäß der
 - (i) die Markierung an der Vorlage mit Licht aus dem Beleuchtungssystem beleuchtet wird, wobei durch den Magnetfeld-Errichtungsmechanismus an dem magnetooptischen Aufzeichnungsträger das Magnetfeld errichtet wird, um an dem magnetooptischen Aufzeichnungsträger ein Bild der Markierung zu erzeugen,
 - (ii) der bewegbare Objektisch danach zum Versetzen des magnetooptischen Aufzeichnungsträgers zu der Detektorvorrichtung hin um eine vorbestimmte Strecke derart be-

wegt wird, daß durch die Detektorvorrichtung irgendeine Abweichung der Lage des erzeugten Bildes in bezug auf eine Bezugslage gemessen wird, und

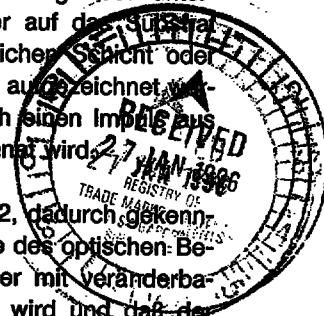
(iii) darauffolgend an dem magnetooptischen Aufzeichnungsträger ein entgegengesetzt gerichtetes Magnetfeld errichtet wird, um das Bild zu löschen.

8. Vorrichtung nach Anspruch 7, dadurch gekennzeichnet, daß die Belichtungsfläche des magnetooptischen Aufzeichnungsträgers auf der gleichen Höhe liegt wie die Belichtungsfläche des Substrats.
9. Vorrichtung nach Anspruch 3, dadurch gekennzeichnet, daß die Aufzeichnungsvorrichtung einen Kühlmechanismus zum Kühlen des fotochromen Materials enthält.
10. Vorrichtung nach Anspruch 9, dadurch gekennzeichnet, daß die Aufzeichnungsvorrichtung ferner einen Heizmechanismus zum Erwärmen des fotochromen Materials enthält.
11. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß der Aufzeichnungsträger eine Glasplatte aus fotochromem Material aufweist.
12. Vorrichtung nach Anspruch 11, dadurch gekennzeichnet, daß die Aufzeichnungsvorrichtung eine Heiz-/Kühlvorrichtung zum Erwärmen und/oder Kühlen der fotochromen Glasplatte enthält.
13. Vorrichtung nach Anspruch 12, dadurch gekennzeichnet, daß die Heiz-/Kühlvorrichtung eine Wärmeisoliervorrichtung enthält, die irgendeine Temperaturänderung in einem Teil der Vorrichtung nahe an der fotochromen Glasplatte verhindert.
14. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß der Magnetfeld-Errichtungsmechanismus (7) eine magnetische Abschirmung (22) zum Verhindern des Errichtens eines Magnetfeldes an einem Teilbereich nahe an dem magnetooptischen Aufzeichnungsträger enthält.
15. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß der Aufzeichnungsträger eine Glasplatte aus einem fotochromen Material aufweist und daß eine Steuereinrichtung dazu ausgelegt ist, auf der fotochromen Glasplatte mehrere Bilder der Markierung an dem Vorlagenbild aufzunehmen.





16. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß eine Steuereinrichtung dazu ausgelegt ist, aufgrund der Erfassung durch die Detektorvorrichtung (9) die Lage des Substrates in einer zur optischen Achse des optischen Projektionssystems (3) senkrechten Ebene zu steuern. 5
17. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß eine Steuereinrichtung dazu vorgesehen ist, aufgrund der durch die Detektorvorrichtung ermittelten Information bezüglich des Bildes auf dem Aufzeichnungsträger irgendeine Abweichung der Vorlage in bezug auf eine Richtung zu erfassen, die in einer zu der optischen Achse des optischen Projektionssystems senkrechten Ebene enthalten ist. 10 15
18. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß eine Steuereinrichtung dazu ausgelegt ist, aufgrund der durch die Detektorvorrichtung ermittelten Information bezüglich des Bildes auf dem Aufzeichnungsträger die Projektionsvergrößerung des optischen Projektionssystems zu ermitteln. 20 25
19. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß eine Steuereinrichtung dazu ausgelegt ist, aufgrund der durch die Detektorvorrichtung erfaßten Information bezüglich des Bildes auf dem Aufzeichnungsträger den durch das optische Projektionssystem herbeigeführten Fokussierzustand zwischen der Vorlage und dem Substrat zu ermitteln. 30 35
20. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß eine Steuereinrichtung dazu ausgelegt ist, aufgrund der durch die Detektorvorrichtung erfaßten Information bezüglich des Bildes auf dem Aufzeichnungsträger irgendeinen Fehler hinsichtlich der Vergrößerung und/oder der Brennpunktlage des optischen Projektionssystems zu ermitteln, wobei die Steuereinrichtung das Ausführen einer Ablauffolge bewirkt, gemäß der nach der Korrektur des ermittelten Fehlers der bewegbare Objektisch zum Anordnen des Substrats an einer Stelle unter der optischen Achse des optischen Projektionssystems bewegt wird und darauffolgend durch Belichtung das Muster der Vorlage auf die Oberfläche des Substrats übertragen wird. 40 45 50
21. Belichtungsverfahren mit Schritten, bei denen ein Vorlagenmuster mit einer daran gebildeten Markierung und an einem bewegbaren Objektisch ein Substrat angebracht werden, mittels eines optischen Beleuchtungssystems die Vorlage beleuchtet wird, um mittels eines optischen Projektionssystems ein Bild der Markierung der Vorlage auf einem löschbar beschriftbaren Aufzeichnungsträger zu erzeugen, der an dem bewegbaren Objektisch an einer Stelle angebracht ist, die gegenüber der Stelle versetzt ist, an der das Substrat gehalten ist, mittels eines optischen Detektorsystems unabhängig von dem Eingriff des optischen Projektionssystems das Bild der Vorlage erfaßt wird und aufgrund der durch das Erfassen des Bildes der Markierung durch das optische Markierung-Detektorsystem erzeugten Information ein Fehler in der Belichtungsanordnung ermittelt wird. 55
22. Verfahren nach Anspruch 21, das ferner das Ermitteln des durch das optische Projektionssystem zwischen der Vorlage und dem Substrat herbeigeführten Fokussierzustandes aufgrund der dem Bild der Markierung entsprechenden und mittels des optischen Detektorsystems erfaßten Information umfaßt.
23. Verfahren nach Anspruch 22, dadurch gekennzeichnet, daß Bilder der Markierung der Vorlage an unterschiedlichen Stellen an der auf das Substrat aufgetragenen fotoempfindlichen Schicht oder dem Aufzeichnungsmaterial erzeugt werden, während der Fokussierzustand zwischen Vorlage und Substrat verändert wird.
24. Verfahren nach Anspruch 22, dadurch gekennzeichnet, daß als Lichtquelle des optischen Beleuchtungssystems ein Impuls laser verwendet wird und daß aufeinanderfolgend Projektionsbelichtungen ausgeführt werden, während das Substrat aufeinanderfolgend in Richtung der optischen Achse des optischen Projektionssystems und in einer zur optischen Achse senkrechten Richtung bewegt wird, so daß die Bilder der Markierung der Vorlage auf unterschiedlichen Stellen an der auf das Substrat aufgetragenen fotoempfindlichen Schicht oder dem Aufzeichnungsmaterial aufgezeichnet werden, wobei jedes Bild durch einen Impuls aus dem Impuls laser aufgezeichnet wird. 50 55
25. Verfahren nach Anspruch 22, dadurch gekennzeichnet, daß als Lichtquelle des optischen Beleuchtungssystems ein Laser mit veränderbarer Wellenlänge verwendet wird und daß der Fokussierzustand zwischen der Vorlage und dem Substrat entsprechend der Ermittlung des Fokussierzustandes durch Verändern der von dem Laser mit der veränderbaren Wellenlänge abgegebenen Wellenlänge eingestellt wird.



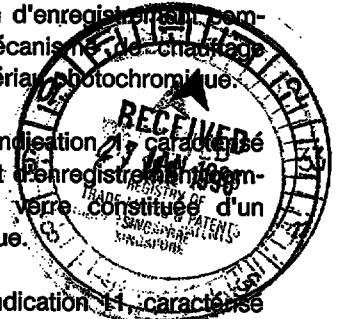


26. Verfahren nach irgendeinem der Ansprüche 21 bis 25, dadurch gekennzeichnet, daß unter Anwendung der ermittelten Information das Substrat mit dem optischen Projektionssystem ausgerichtet wird und danach das Plättchen mittels des optischen Projektionssystems mit dem Vorlagenmuster belichtet wird.

Revendications

1. Appareil d'exposition comprenant une platine mobile (5) pour porter un substrat (4); un système d'éclairage (1) pour éclairer un motif d'un original au moyen d'une lumière d'exposition de longueur d'onde prédéterminée et un système optique de projection (3) pour projeter le motif de l'original éclairé par ladite lumière sur ledit substrat (4); caractérisé par un moyen d'enregistrement comportant un support d'enregistrement (6) monté sur ladite platine en une position décalée par rapport audit substrat, pour enregistrer une image d'une marque de l'original projeté à travers ledit système optique de projection en réponse à l'éclairage de la marque par une lumière de longueur d'onde sensiblement identique à celle de la lumière d'exposition, ledit support d'enregistrement comportant un matériau d'enregistrement effaçable et réinscriptible disposé sur ladite platine mobile; et un dispositif de détection de marque (9) pour détecter photoélectriquement l'image de la marque telle qu'elle est enregistrée sur ledit support d'enregistrement (6), indépendamment dudit système optique de projection, une erreur affectant ledit appareil d'exposition pouvant ainsi être détectée sur la base d'une information produite par la détection de l'image de la marque par ledit dispositif de détection de marque.
2. Appareil selon la revendication 1, caractérisé en ce que ledit support d'enregistrement (6) comprend un élément d'enregistrement magnéto-optique.
3. Appareil selon la revendication 1, caractérisé en ce que ledit support d'enregistrement (6) comprend un matériau photochromique.
4. Appareil selon la revendication 1, 2 ou 3, caractérisé en ce que ledit support d'enregistrement (6) est monté de façon amovible sur ladite platine mobile.
5. Appareil selon la revendication 1, caractérisé en ce que ledit moyen de détection (9) comprend un microscope à polarisation.

6. Appareil selon la revendication 2, caractérisé en ce que ledit moyen d'enregistrement (6) comporte un mécanisme (7) ayant pour effet d'appliquer audit support d'enregistrement magnéto-optique disposé sur ladite platine mobile, un champ magnétique dans une direction parallèle à un axe optique dudit système optique de projection.
7. Appareil selon la revendication 6, caractérisé en ce que des moyens de commande (80) sont adaptés à établir une séquence selon laquelle (i) la marque présente sur l'original est exposée à de la lumière provenant dudit système d'éclairage avec le champ magnétique appliqué audit support d'enregistrement magnéto-optique par ledit mécanisme d'application de champ magnétique, pour former une image de la marque sur ledit support d'enregistrement magnéto-optique; (ii) ladite platine mobile est ensuite entraînée pour déplacer ledit support d'enregistrement magnéto-optique vers ledit moyen de détection d'une distance prédéterminée pour qu'un éventuel écart de position de l'image formée par rapport à une position de référence soit mesuré par ledit moyen de détection; et (iii) un champ magnétique inverse est ensuite appliqué audit support d'enregistrement magnéto-optique pour effacer l'image.
8. Appareil selon la revendication 7, caractérisé en ce que la surface d'exposition dudit support d'enregistrement magnéto-optique est à la même hauteur que la surface d'exposition du substrat.
9. Appareil selon la revendication 3, caractérisé en ce que ledit moyen d'enregistrement (6) comporte un mécanisme de refroidissement pour refroidir ledit matériau photochromique.
10. Appareil selon la revendication 9, caractérisé en ce que ledit moyen d'enregistrement comporte en outre un mécanisme de chauffage pour chauffer ledit matériau photochromique.
11. Appareil selon la revendication 1, caractérisé en ce que ledit support d'enregistrement comprend une plaque de verre constituée d'un matériau photochromique.
12. Appareil selon la revendication 11, caractérisé en ce que ledit moyen d'enregistrement comporte un dispositif de chauffage/refroidissement pour chauffer et/ou refroidir ladite plaque de verre photochromique.





13. Appareil selon la revendication 12, caractérisé en ce que ledit dispositif de chauffage/refroidissement comporte un moyen thermiquement isolant ayant pour effet d'éviter toute variation de température dans une partie dudit appareil proche de ladite plaque de verre photochromique.
14. Appareil selon la revendication 6, caractérisé en ce que ledit mécanisme d'application de champ magnétique (7) comporte un blindage magnétique (22) pour empêcher qu'un champ magnétique ne soit appliqué à une partie proche dudit support d'enregistrement magnéto-optique.
15. Appareil selon la revendication 1, caractérisé en ce que ledit support d'enregistrement comprend une plaque de verre constituée d'un matériau photochromique, et en ce que ledit moyen de commande est adapté à recevoir, sur ladite plaque de verre photochromique, plusieurs images de la marque se trouvant sur l'image originale.
16. Appareil selon la revendication 1, caractérisé en ce que des moyens de commande sont adaptés à commander, sur la base de la détection effectuée par ledit moyen de détection (9), la position du substrat dans un plan perpendiculaire à l'axe optique dudit système optique de projection (3).
17. Appareil selon la revendication 1, caractérisé en ce que des moyens de commande sont prévus pour détecter, sur la base de l'information concernant l'image se trouvant sur ledit support d'enregistrement et détectée par ledit moyen de détection, un éventuel écart entre l'original et une direction contenue dans un plan perpendiculaire à l'axe optique dudit système optique de projection.
18. Appareil selon la revendication 1, caractérisé en ce que des moyens de commande sont adaptés à détecter l'agrandissement de projection dudit système optique de projection, sur la base de l'information concernant l'image se trouvant sur ledit support d'enregistrement et détectée par ledit moyen de détection.
19. Appareil selon la revendication 1, caractérisé en ce que des moyens de commande sont adaptés à détecter, sur la base de l'information concernant l'image se trouvant sur ledit support d'enregistrement et détectée par ledit moyen de détection, l'état de la focalisation établie entre l'original et le substrat par ledit

système optique de projection.

20. Appareil selon la revendication 1, caractérisé en ce que des moyens de commande sont adaptés à détecter une éventuelle erreur d'agrandissement et/ou de position de focalisation dudit système optique de projection, sur la base de l'information concernant l'image se trouvant sur ledit support d'enregistrement et détectée par ledit moyen de détection, et en ce que ledit moyen de commande a pour effet d'établir une séquence selon laquelle, après correction de l'erreur détectée, ladite platine mobile est déplacée pour positionner le substrat à une position située sous un axe optique dudit système optique de projection et le motif de l'original est ensuite transféré, par exposition, sur la surface du substrat.
21. Procédé d'exposition comprenant les étapes consistant à monter un motif original ayant une marque formée sur celui-ci et un substrat sur une platine mobile; éclairer l'original par utilisation d'un système optique d'éclairage pour former, par utilisation d'un système optique de projection, une image de la marque de l'original sur un support d'enregistrement réinscriptible disposé sur la platine mobile en une position décalée par rapport à la position à laquelle le substrat est maintenu; détecter l'image de la marque par utilisation d'un système optique de détection indépendamment de l'intervention du système optique de projection, et détecter une erreur affectant ledit appareil d'exposition sur la base de l'information produite par détection de l'image de la marque par ledit système optique de détection de marque.
22. Procédé selon la revendication 21, consistant en outre à détecter l'état de focalisation établi entre l'original et le substrat par le système optique de projection, sur la base de l'information correspondant à l'image de la marque et détectée par le système optique de détection.
23. Procédé selon la revendication 22, caractérisé en ce qu'on forme des images de la marque de l'original à des positions différentes sur la couche photosensible ou sur le support d'enregistrement disposé sur le substrat, tout en modifiant l'état de focalisation entre l'original et le substrat.
24. Procédé selon la revendication 22, caractérisé en ce qu'on utilise un laser pulsé comme source de lumière du système optique d'éclairage, et en ce qu'on effectue successivement des expositions de projection en déplaçant le





substrat successivement dans une direction de l'axe optique du système optique de projection et dans une direction perpendiculaire à l'axe optique, de façon que les images de la marque de l'original soient imprimées à des positions différentes sur la couche photosensible ou sur le support d'enregistrement disposé sur le substrat, chaque image étant imprimée par une impulsion provenant du laser pulsé.

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25. Procédé selon la revendication 22, caractérisé en ce qu'un laser à longueur d'onde variable est utilisé comme source de lumière du système optique d'éclairage, et en ce que l'état de focalisation entre l'original et le substrat est ajusté sur la base de la détection de l'état de focalisation et par modification de la longueur d'onde de la lumière émanant du laser à longueur d'onde variable.

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26. Procédé selon l'une quelconque des revendications 21-25, caractérisé en ce que le substrat est aligné avec le système optique de projection par utilisation de l'information obtenue, et en ce que la plaquette est ensuite exposée au motif original par utilisation du système optique de projection.

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