

ALIGNMENT AND EXPOSURE APPARATUSFIELD OF THE INVENTION AND RELATED ARTS

This invention relates to an exposure
5 apparatus for use in the manufacture of semiconductor
microcircuit devices such as integrated circuits (ICs),
large scaled integrated circuits (LSIs) and the like.
More particularly, the invention is concerned with a
unique process and system in relation to alignment and
10 exposure in an alignment and exposure apparatus called
a "mask aligner".

Resolution and alignment accuracy are basic
performances required in a mask aligner. Also, the
processing ability (throughput) will be another
15 essential performance in the point that the mask
aligner is a productive machine. Tendency to further
miniaturization and higher capacity of semiconductor
devices has forced further improvements in the
resolution and alignment accuracy.

20 With the miniaturization of devices, there has
occurred transition in an exposure process adopted in
mask aligners: that is, there have been developed
contact/proximity type, 1:1 mirror projection type and
lens projection type in this order. At present, a
25 step-and-repeat type projection exposure apparatus
(called a "stepper") using exposure light energy of a
wavelength 350 - 450 nm, becomes prevailing.

Further, as an aligner for manufacture of next era devices, such a stepper which uses a light source that can supply light of shorter wavelength (for example, a stepper using as an exposure beam a light having relatively high intensity and short wavelength of an order of 250 nm, such as a laser beam from a KrF excimer laser, for example), is considered as being effective. In this type of mask aligners, higher precision is required, along with the improvements in the resolution, in regard to the pattern overlay or superposition accuracy related to overlaying a circuit pattern of a mask or reticle upon a pattern already formed on a wafer. In a case of 16 mega-DRAM, for example, for a resolution of 0.5 micron, a pattern overlay accuracy of about 0.15 micron and an alignment accuracy of about 0.1 micron are required.

Thus, development of a unique alignment system that ensures high-precision pattern overlay has been desired. In an attempt to meet this, improved alignment systems have been proposed in Japanese Laid-Open Patent Applications, Laid-Open Nos. Sho 61-263123 and Sho 62-94932.

The alignment systems disclosed in these publications utilize, for the alignment purpose, a wafer chuck adapted to hold thereon a wafer by attraction. An alignment mark is provided on the wafer chuck, and by using an off-axis microscope and an X-Y

stage the relative position of an alignment mark formed on the wafer and the alignment mark of the wafer chuck is detected and memorised in a memory. After this, the relative position of the alignment mark of the wafer
5 chuck and an alignment mark provided on a reticle is detecting by using a projection lens system (provided for the projection exposure) and the X-Y stage. By this, the positional relationship between the reticle and the wafer can be detected.

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SUMMARY OF THE INVENTION

According to the present invention a step-and-repeat type projection exposure apparatus for projecting a ~~[device pattern of a]~~ reticle on different zones of a
15 workpiece in sequence through a projection optical system, wherein the apparatus includes a reticle holder for holding the reticle, a workpiece holder for holding the workpiece and a movable stage for holding the workpiece holder, is characterised in that:

20 the workpiece holder has a plurality of recording areas each being provided by a magneto-optical material, or a photochromic material, the recording areas being located around the periphery of the workpiece as it is held by the workpiece holder, wherein the movable stage
25 is adapted to move the workpiece holder so that on each

of the recording areas an image of a mark of the reticle is projected and thus recorded through the projection optical system; and

5 detecting means for detecting the images recorded on the recording areas of the workpiece holder and means for determining, on the basis of obtained data, the coordinate of the pattern array on the workpiece for the step-and-repeat exposures of the workpiece.

How the invention may be carried out will now be
10 described by way of example only and with reference to the accompanying drawings in which:

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic and diagrammatic view of an
15 alignment and exposure apparatus according to an embodiment of the present invention;

Figure 2 is a flow chart showing the sequence of alignment and exposure adopted in the alignment and exposure apparatus of the Figure 1 embodiment;

20 Figure 3 is a schematic top plan view of a reticle prepared for an N-th process;

Figures 4A and 4B are top plan views, respectively, showing a wafer and a wafer chuck for the N-th process.

Figure 5 is a schematic and diagrammatic view of an alignment and exposure apparatus according to another embodiment of the present invention.

Figure 6 is a fragmentary section of a wafer chuck.

Figure 7 is a fragmentary view showing a magnetic field producing means.

Figure 8 is a representation showing the manner of erasing a magnetic image by the magnetic field producing means.

Figure 9 is a schematic and diagrammatic view of an alignment and exposure apparatus according to a further embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 shows an alignment and exposure apparatus according to a first embodiment of the present invention.

The main assembly of the exposure system is carried by a surface plate 1. Disposed on the surface plate 1 is a wafer stage 2 which is adapted to support a wafer chuck 3 and a wafer 4, held on the chuck 3 by attraction, for movement in a plane (X-Y plane) perpendicular to an optical axis AX of a projection

lens system 5 and in a direction (Z-axis direction) along the optical axis AX. The wafer stage 2 has formed thereon an optical mirror 6 on which a beam 7 from a laser interferometer 70 is projected, whereby
5 the amount of movement of the wafer stage 2 can be measured in a known manner. Also, the position coordinate of the wafer stage 2 in the X-Y plane can be detected accurately. In response to a signal as produced by the interferometer 70, the movement of the
10 wafer stage 2 through a specified distance can be controlled in a known manner. Disposed above the projection lens system 5 is a reticle 9 which is held by a reticle holder 8. The reticle holder 8 is movable in a plane parallel to the X-Y plane. Disposed above
15 the reticle 9 is an illumination optical system generally denoted at reference A. When light is supplied to the reticle 9 from the illumination optical system, a circuit pattern formed on the reticle 9 can be transferred by projection onto a resist or
20 photoresist layer formed on the wafer 4, through the projection lens system 5.

The illumination optical system A comprises a light source 10 such as a super Hg lamp, first to third condenser lenses 11 - 13 provided to uniformly
25 illuminate the surface of the reticle 9 with light supplied by the light source 10, and first and second mirrors 14 and 15 provided to bend or deflect the

light. Shutter 16 is provided to control the exposure.

The second and third condenser lenses 12 and 13 and the second mirror 15 are arranged to cooperate with each other to define, at a position denoted at B in Figure 1, a plane which is optically conjugate with a pattern bearing surface 17 of the reticle 9 (a surface facing the projection lens system 5). By disposing an appropriate masking member such as at 20 on the plane B, only a desired portion of the reticle 9 can be illuminated. The selective illumination using such a masking blade means 20 is known in the art, as disclosed in U.S. Patent No. 4,474,463, for example. In this embodiment, four independently movable blades are used as the blade means 20, the blades being adapted to be actuated by a driving circuit 72 to variably define a desired aperture of rectangular shape.

Disposed close to the projection lens system 5 is an off-axis alignment optical system C having an optical axis AX' which is parallel to the optical axis of the projection lens system 5. The alignment optical system C is arranged such that light emanating from a halogen lamp 22 is concentrated by a condensing mirror 23 and a condensing lens 24 and, after being directed by way of a first polarization plate 31, a half mirror 25, an objective lens 26 and a swingable mirror 27, it impinges on the wafer 4 surface or a portion of the

wafer chuck 3 surface, denoted at 40 in Figure 1. The light reflected from the surface goes along its oncoming path and, after being reflected or transmitted by the swingable mirror 27 and the objective lens 26,
5 it is deflected upwardly, at a right angle, by the half mirror 25. Thus, through a relay lens 28, the light illuminates a reference mark plate 310, whereby a pattern provided on the wafer 4 surface or the chuck 3 surface is once imaged on the reference mark plate 310.

10 Erector 32 is adapted to image, on the surface 30 of an image pickup tube 29, a reference mark formed on the reference mark plate 310 and the image of the pattern of the wafer 4, for example. Second polarization plate 33 is disposed between the erector
15 32 and the image pickup tube 29. Thus, only the light having been polarized in a predetermined direction can be received by the image pickup tube 29. Namely, the alignment optical system C provides a polarization microscope.

20 Signals from the image pickup tube 29 are transmitted through a CCU 71 to an image processing circuit 73, in which the image of the reference mark of the reference mark plate 310, an image of an alignment mark pattern of the wafer 4 and an image of a magnetic
25 pattern formed on the chuck 3 (which will be described later) can be processed. For example, the image processing circuit 73 is operable to detect the

positional relationship of the wafer alignment mark or the magnetic pattern with the reference mark of the reference mark plate 310.

At a portion of the wafer chuck 3 surface, which is outside a wafer 4 as it is attracted to the chuck 3 (namely, the portion of the wafer chuck 3 that does not contact the wafer 4), there is provided a protrusion 40 whose surface has a height, with respect to the direction of the optical axis AX, which is substantially equal to the height of the wafer 4 surface. The surface of the protrusion 40 is covered with a magneto-optic recording material 106. As an example, the magneto-optic recording material may be made of a well-known rare earth transition metal alloy.

In a magneto-optic recording material, normally the direction of magnetization is uniformly aligned (e.g. upwardly). If, however, an inversive magnetic field (e.g. downward magnetic field) is applied to the magneto-optic recording material and where a light energy is supplied thereto, there occurs inversion of the direction of magnetization only in such portion that has been exposed to the light. Thus, there appears a magnetic pattern (a pattern defined by a change in a magnetic domain) that is provided by a portion in which the magnetization is normal and a portion in which the magnetization is reversed, the thus formed pattern can be observed through the

alignment optical system C which constitutes a polarization microscope.

Further, when an intense magnetic field inverse to that applied during the recording (e.g. an upward magnetic field) is applied to the magneto-optic recording material, the magnetization returns to its initial normal state. Thus, with this type of recording material, both the writing of a pattern and the erasing of the recorded pattern are possible.

Figure 6 is a fragmentary section of a wafer chuck 3 usable in this embodiment. Although many varieties of arrangements are usable as the means for producing weak magnetic lines of force (magnetic field) for formation of such a magnetic image, in this embodiment use is made of a permanent magnet means which is embedded in the wafer chuck 3. This allows that the system is kept continuously ready for formation of a magnetic image. As contrasted thereto, use of a coil or otherwise causes a possibility of generation of heat due to an electric current supplied to the coil and the resistance thereof. Use of a permanent magnet means is inexpensive and sure.

The wafer chuck 3 is provided at its wafer holding surface with a seal surface 101 of ring-like shape, formed at peripheral portion of the chuck, and an inside pin-chuck means having a number of pins 102. The pin-chuck means is evacuated to vacuum through a

passageway 103 formed in the chuck, whereby a wafer 4 can be attracted to the chuck and the flatness of the wafer can be corrected.

Disposed around the wafer chuck 3 is a ring 5 105 which is coupled to the chuck 3 by bolts 104. On the surface of the ring 105 a magneto-optic recording material 106 is formed in a layer structure by an evaporation or sputtering process. As described hereinbefore, the position of the surface of the 10 recording material with respect to the direction of the optical axis AX of the projection lens 5 is substantially the same as the surface position of the wafer 4.

The ring 105 is formed with a groove to which 15 a permanent magnet 107 is bonded. The permanent magnet 107 has N-poles at its upper part and S-poles at its lower part, as illustrated, so that the permanent magnet produces magnetic lines of force (109) as depicted by broken lines. The permanent magnet 107 is 20 so disposed that its magnetic lines of force denoted at 109 intersect the recording surface of the magneto-optic recording material layer 106 approximately perpendicularly.

Figure 7 shows a magnetic field producing 25 means which is provided about the projection lens system 5.

In Figure 7, denoted at 201 is a magnetic

field producing means which comprises a magnetic head. The magnetic head 201 is used to erase a magnetic image recorded on the magneto-optic recording material 106.

The sequence of erasing a magnetic image is such that: First, the wafer stage 2 is displaced so as to bring such portion of the magneto-optic recording material 106, in which a magnetic image is formed, to a site below the erasing magnetic head 201. As shown in Figure 8, electric current is then supplied by a driving circuit 701 to a coil 202 of the magnetic head 201, whereby magnetic lines of force are produced at an iron core 203 which is provided inside the coil 202.

More specifically, in Figure 6, the electric current is flown through the coil 202 so that N-pole is defined at the magnetic head 201 side. Namely, the coil 202 is energized to assure that N-pole is defined at the chuck 3 side of the core 203 while S-pole is defined at an end portion of the core 203 remote from the chuck 3. If the magnetic lines of force is sufficiently intense as compared with the magnetic lines of force of the permanent magnet 107, it overcomes the magnetic lines of force of the permanent magnet 107 being embedded within the chuck 3, such that magnetic lines of force inverse to those by the permanent magnet 107 is formed substantially perpendicularly to the magneto-optic recording material layer 106. As a result, the magnetic image can be

erased.

In Figure 6, only one magnetic field (magnetic lines of force) producing means 201 is illustrated. Actually, however, a plurality of such producing means
5 may preferably be provided around the projection lens system 5. In that case, only a slight movement of the stage is sufficient to quickly erase a magnetic image formed at any site on the wafer chuck 3.

Referring now to the flow chart of Figure 2
10 and the top plan view of a reticle of Figure 3 as well as top plan views of a wafer and a wafer chuck of Figures 4A and 4B, an example of the sequence of alignment and exposure that can be adopted in the exposure apparatus of the present invention will be
15 explained.

Assuming now that the alignment and exposure procedure which is just going to be explained pertains to an N-th process for executing the patterning of an N-th layer of each semiconductor device, Figure 3 just
20 shows a reticle 50 for the N-th process. In Figure 3, in a portion 52 which corresponds to a scribe line surrounding an actual device pattern region 51, there are provided wafer automatic alignment marks (called "AA marks") 53L and 53R which are to be used in a
25 process or processes following the N-th process. Although these marks 53L and 53R can be used each as a mark to be projected upon a magneto-optic recording

material layer provided at a peripheral portion of a wafer chuck, in this embodiment those marks 55D, 55U, 55L and 55R, which are formed in such region that corresponds to a range outside the actual device pattern region 51 (52) and inside the effective exposure region 54 (effective view field of the projection lens system 5), are used for the pattern recording to be made on the magneto-optic recording material layer 106 provided on the chuck 3.

10 In the flow chart of Figure 2, first a wafer 60 having been subjected to an (N-1)-th process is placed on and held by the wafer chuck 3 by attraction (Step 101). Figure 4A shows this state. In Figure 4A, rectangular patterns 61 arrayed on the wafer 60 are
15 those actual device areas (shot areas) having been formed up to the (N-1)-th process. In the scribe lines between those actual device areas, there are wafer AA marks 62 for the N-th process, having been prepared during the preceding process. At this time, no pattern
20 is formed on the magneto-optic recording material layer 40 at the peripheral portion of the wafer chuck 3.

 At Step 102 in the flow chart, wafer AA marks 62 provided at least at two spaced sites are detected through the alignment optical system C, and the wafer
25 chuck 3 is rotationally adjusted in a θ direction so that the direction of array of the shot areas on the wafer 60 is aligned with a predetermined reference.

direction of the apparatus (for example, an X-axis direction). As the wafer array direction is aligned with the reference direction, the 0 position of the wafer 4 is fixed. Since the operation necessary for
5 this is substantially the same as that of prealignment made in a conventional stepper by using an off-axis microscope, description of details will be omitted here. Of course, detected values (Δu_i , Δv_i) related to each wafer AA mark position as the wafer 0 position is
10 fixed, as well as the coordinate position (x_i , y_i) of the stage 2 at each corresponding time are memorized through the image processing circuit 73, the laser interferometer 70 and a CPU 74 into a memory 75.

Subsequently, at Step 103, formation of a
15 magnetic image or images is executed. To this end, the wafer stage 2 is moved sequentially to preselected sites (on X-Y position coordinate) having been selected for formation of magnetic images, wherein at each site the shutter 16 is opened to expose alignment marks 55
20 of the reticle 50 to light, whereby through the projection lens system 5 magnetic images of the exposed alignment marks 55 are formed in a preselected portion of the magneto-optic recording material layer 40 provided on the wafer chuck 3. Until exposures of a
25 predetermined number are completed, the "step and exposure" is repeated. Of course, the coordinate position (E_{xj} , E_{yj}) of the stage at each exposure is

read and stored into the memory 75. The selection of the magnetic image forming alignment marks 55D, 55U, 55L and 55R of the reticle 50, for printing an image at an appropriate position on the magneto-optic recording material layer 40, is made under the influence of the masking blade means 20. Also, the masking blade means 20 is used to prevent that any effective shot area on the wafer is exposed during the exposure of the magnetic image forming marks 55D - 55R. The magnetic images formed as a result of these exposures are illustrated in Figure 4B.

In this embodiment, as shown in Figure 4B, four exposures may be made to form eight magnetic image marks 65 at upper, lower, left and right portions of the chuck, as viewed in this Figure.

At Step 104, by using the alignment optical system C and the laser interferometer 70, the position of each magnetic image mark 65j ($j = L, R, U, D \dots$) as well as the position of each wafer AA mark 62i ($i = 1, 2, 3, \dots$), namely, $(\Delta u_j, \Delta v_j)$ and $(\Delta u_i, \Delta v_i)$, are detected and, additionally, the coordinate position (x_j, y_j) (x_i, y_i) of the stage at each corresponding time is read. Here, the magnetic image marks and the wafer AA marks may be read in any desired order. However, it is preferable to so determine the order as to reduce the total time to the minimum.

It is to be noted here that the number of

wafer AA marks to be detected, the number of shots
for printing magnetic images, the number of marks to be
selected as the subject of printing, the number of
magnetic images to be detected, the times of detecting
5 operations to be made for each magnetic image and the
like, during Steps 102 - 104, should be determined in
accordance with the required overlay precision for the
N-th process.

Thus, as regards the wafer AA marks at Step
10 104, for example, the maximum number is that of all the
marks of all the shot areas. As for the minimum, on
the other hand, use of the data at Step 102 may be
considered in some case as being sufficient, such that
the number of detections at Step 104 may be made zero.

15 In this embodiment, at some of the steps
described hereinbefore, the projection magnification of
the projection lens system 5 and any 0 error of the
reticle 9 can be checked. Also, in some occasion, any
positional error of the wafer 4 in the direction of the
20 optical axis can be detected by detecting contrast of
the magnetic image, for example.

At Step 105, computation may be made on the
basis of the data obtained at Steps 102 - 104, for
determination of the actual array coordinate of the
25 device patterns (shot areas) on the wafer, which
coordinate is to be used in the "step-and-repeat"
exposure at a later stage. While, also in this case,

the coordinate can be calculated in various ways, basically, such coordinate system that has been obtained during the formation and detection of the magnetic images may be used as a reference to correct the coordinate data of the wafer AA mark. Then, at Step 106, sequential stepwise movements of the wafer stage 2 accompanied by exposures are made in accordance with the coordinate of the device pattern array as determined at Step 105.

10 In this occasion, the masking blade means 20 is used to restrict the illumination range by the illumination light, such that the illumination light can be directed to the circuit pattern surface 17 of the reticle 9 but the illumination light is prevented from being directed to the magnetic image forming alignment marks 55 of the reticle 9.

At Step 107, the magnetic images having been formed in a portion of the magneto-optic recording material 40 on the wafer chuck 3 are erased. Where the wafer chuck 3 itself is provided with a suitable erasing means, the magnetic image may be erased before Step 106 or, alternatively, it may be erased in the course of Step 105 or 106.

Where an erasing means is to be annexed to the wafer chuck 3 itself, the above-described magnetic head 201 may be embedded within the chuck. In such structure, a magnetic image can be erased at any wafer

stage position, without moving the stage 2. Further, such an embedded magnetic head may be used also for production of a magnetic field for formation of a magnetic image.

5 The alignment procedure is not limited to the described one. Namely, what is to be made in this embodiment, after fixation of the 0 position of the wafer, is that:

 (1) Each of preselected alignment marks on a wafer
10 4 is introduced into a view field of the alignment optical system C, and a data of the detected position of the mark as well as a data of the stage position at a corresponding time are stored as information;

 (2) Magnetic image mark of the reticle is formed
15 at a preset position and, simultaneously therewith, a data concerning the position of the stage at that time is detected and memorized, while, on the other hand, each magnetic image mark is introduced into the view field of the alignment optical system C and a data of
20 the detected position of the image mark as well as a data of the position of the stage at that time are stored as information; and

 (3) By using the data obtained at (1) and (2), the coordinate of the actual device pattern (shot area)
25 array for the "step and exposure" is calculated.

 The order of these processings is not important. Further, it is sufficient that a magnetic

image is erased before the succeeding formation of a fresh magnetic image in the same region.

With the alignment process described above, the wafer stage 2 has to be moved frequently. If, therefore, the process is executed exactly in accordance with the sequence of the flow chart of Figure 2, the total amount of movement of the wafer stage 2 becomes large (i.e. the time for movement becomes long), with a result of prolonged processing time per one wafer.

Actually, therefore, since the positions of wafer alignment marks to be detected and the positions of magnetic images to be formed and detected are predetermined, an appropriate sequence may preferably be determined to reduce the time for moving the stage, and this can be easily programmed by using a CPU.

In accordance with the alignment and exposure apparatus of the present embodiment, although it uses an off-axis alignment system, the inconveniences in respect to precision that has been involved conventionally can be alleviated significantly and, therefore, the precision can be improved significantly. Further, there is a specific advantage that the above-described effects can be accomplished without any weak point inherent to the system and without a particular obstruction to embodying the structure.

As contrasted to the foregoing embodiment, a

magneto-optic recording material may be replaced by a photochromic material. Where a photochromic material is used, there are advantages that a particular condition of using a magnetic field for writing is not
5 necessary and that, since the photochromic material shows accumulation type reaction, even if the exposing energy is low, an image can surely be formed although a prolonged time is necessary. Further, as regards the erasing, an image can easily be erased by using heat or
10 white light. Additionally, where a photochromic material is used, it is not necessary to provide the off-axis alignment optical system by using a polarization microscope. A traditional off-axis alignment scope or an ordinary microscope may be used.

15 On the other hand, the magneto-optic recording material used in the foregoing embodiment has no energy accumulation property and, when the optical energy per unit time becomes lower than a certain critical value, no magnetic image can be formed. Thus, it is necessary
20 to set the illuminance of the irradiating light upon the image surface at a sufficient level.

In consideration of this, although the structure may become somewhat complicated, it may be preferable that, as shown in Figure 5 which represents
25 a second embodiment of the present invention, an optical energy which is stronger than that of the regular exposure illumination light, is

concentratingly applied to the magnetic image forming mark portion. More specifically, in the example of Figure 5, a mirror 90 which can be used, for the regular exposure, to direct the light from a light source 91 to the illumination optical system A, is made retractable, such that for formation of a magnetic image the mirror 90 is retracted to a position as depicted at reference numeral 90'. This allows that the light from the light source 91 is directly introduced to fibers 92, which are provided separately, the light emanating from the fibers being directly projected upon those portions 95 of the reticle 9 upper surface at which magnetic image forming alignment marks are provided. Alternatively, the fibers 92 may be extended close to the masking blade means 20, so that the wafer chuck 3 is indirectly irradiated and exposed to the light from the fibers 92 by way of an optical arrangement disposed downstream of the masking surface 95' with respect to the path of light. Further, in place of using the fibers 92, a separate laser light source for producing light of high intensity may be provided to allow that the portions 95 of the reticle upper surface may be irradiated and exposed with the laser beam from such a laser source.

Further, as the light source 91 shown in Figure 5, a KrF excimer laser may be used. Namely, where the invention is to be embodied in an excimer

laser stepper, each magnetic image can be printed while continuously moving a wafer stage 2, without stopping the same. Namely, what can be called a "flash on the fly" process may be used, to reduce the time and to
5 improve the throughput.

An excimer laser is a pulsed laser, and its pulse duration is about 20 nsec/pls. If the stage moves at a speed of 100 mm/sec, then for 20 nsec it runs through 0.02 micron. Thus, there does not occur a
10 problem of "image flow". Also, while the exposure of actual device patterns according to the "flash on the fly" process, as is known in the art, is based on the possibility that the stage passes a certain target point which is predetermined at least with respect to
15 two axis-directions of an X-Y coordinate, and the exposure is executed just at the moment of passage. However, the "flash on the fly" process which may be adopted in this embodiment is only such that the exposure is made during a substantial time period of
20 passage of the stage through a certain tolerance region of a certain range and it is sufficient that the coordinate position of the stage just at the moment of exposure is read by using a laser interferometer. Therefore, clearly it can be executed very easily as
25 compared with the former.

The KrF excimer laser stepper shown in Figure 5 includes a band narrowing means which may comprise an

etalon or a grating, for example, and which is provided within the light source device 91. By this band narrowing means, the bandwidth $\Delta\lambda$ of the KrF laser can be narrowed to an order of $\Delta\lambda = 0.05$ nm. Further, the
5 projection lens system 5 is provided by plural lens elements all of which are made of SiO_2 , and the projection lens system is adapted to sufficiently transmit the KrF laser beam of a wavelength λ of an order of $\lambda = 248.4$ nm.

10 Figure 9 is a schematic view of an alignment and exposure apparatus according to a third embodiment of the present invention. Like numerals are assigned to those elements having similar or corresponding functions as of those shown in Figures 1 and 5. Also,
15 for simplification, the illumination optical system A is diagrammatically illustrated. For the same reason, some elements of an off-axis alignment scope C are not illustrated. While the scope C comprises a
20 polarization microscope as in the foregoing embodiment, no mirror such as at 27 for deflecting the optical path is used.

An important feature of the present embodiment resides in that a reticle alignment scope B is utilized to illuminate a magnetic image forming alignment mark
25 53 of the reticle 9, whereby a magnetic image of the mark is formed in a portion of the magneto-optic recording material layer provided on a wafer chuck 3.

The reticle alignment scope B includes a stop 120 for restricting the range of illumination, an image pickup device 110 and an objective optical system 140, and is operable to extract a portion of the
5 photoprinting light from the illumination optical system A (for example, an excimer laser beam), to illuminate a reticle alignment mark or marks, not shown. Then, through the objective optical system 140, an image of the reticle alignment mark is picked up by
10 the image pickup device 110, and any deviation of the reticle alignment mark with respect to a reference provided at a stationary portion of the exposure apparatus is detected. On the basis of the result of detection, the position of the reticle 9 can be
15 adjusted (aligned).

The objective optical system 140 is movable or translatable along the surface (pattern bearing surface) of the reticle 9. Thus, regardless of the position of the reticle alignment mark, the same can be
20 detected by the optical system 140. In this embodiment, after completion of the reticle 9 alignment, the position of the objective optical system 140 is changed to allow illumination of a magnetic image forming mark 53. Then, with the light from the
25 reticle alignment scope, the mark 53 is illuminated and, through the projection lens system 5, an image of the mark 53 is projected upon a magneto-optic recording

material layer provided on the wafer chuck 3. By this, a magnetic image is formed in a portion of the magneto-optic recording material layer. The reticle-to-wafer alignment using the thus formed magnetic image can be
5 made essentially in the same way as having been described with reference to the foregoing embodiments. Therefore, description thereof will be omitted here.

In this embodiment, the thus formed magnetic image can be used for measurement of the distance
10 between optical axes of the projection lens system 5 and the off-axis alignment scope C. The distance between these optical axes is called a "base line" and it is one of important system parameters in an exposure apparatus that includes an off-axis alignment scope
15 such as at C. That is, in such exposure apparatus usually the position of an alignment mark on a wafer 4 is detected through an off-axis alignment scope C and then a wafer stage 2 is displaced, in accordance with a preset value for the distance between the optical axes,
20 to position the wafer 4 with respect to the position whereat a pattern is to be projected through the projection lens system 5. Actually, however, the distance between the optical axes is variable with time. Thus, it is desirable to accurately detect the
25 change in the distance or the changed distance between the optical axes.

In this embodiment, in accordance with the

data concerning the distance between the optical axes, having been memorized in preparation, the wafer stage 3 is displaced to introduce a magnetic image, formed in a portion of the magneto-optic recording layer on the
5 wafer chuck 3, into the view field of the off-axis alignment scope C. Then, the position of the magnetic image with respect to a predetermined reference provided in the alignment scope C is detected. On the basis of the detection, the data related to the
10 distance between the optical axes can be corrected and thus the current distance can be detected exactly.

In accordance with the present invention, as has hitherto been described, a wafer chuck for holding a wafer by attraction is provided with a recording
15 layer made of, for example, a magneto-optic recording material or a photochromic material. One or more alignment marks of a reticle are transferred through a projection system onto this recording layer and, on the basis of a positional relationship between the
20 transferred image of the alignment mark and an alignment mark provided on the wafer, the reticle-to-wafer alignment or the alignment of each shot area of the wafer to the reticle can be made exactly.

Accordingly, regardless of a wafer process,
25 high-precision alignment is always assured.

Since the magneto-optic recording material or the photochromic material is such a recording material

that allows both the writing and the erasing, there is a specific advantage that the recording material can be used repeatedly.

5 Additionally, on the basis of the state of an
alignment mark image as transferred onto a recording
layer of a wafer chuck (i.e., by detecting the position
or contrast of the image), any error in the
magnification of a projection lens system, any error in
the rotational (θ) direction of a reticle, any error in
10 the distance (base line) between the optical axes of
the projection lens system and an off-axis microscope,
any error in the position of the wafer with respect to
the direction of the optical axis of the projection
lens system (i.e., focus error), and the like can be
15 detected.

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CLAIMS

1. A step-and-repeat type projection exposure apparatus for projecting ~~[a device pattern of]~~ a reticle on different zones of a workpiece in sequence through a projection
5 optical system, wherein the apparatus includes a reticle holder for holding the reticle, a workpiece holder for holding the workpiece and a movable stage for holding the workpiece holder, characterised in that:

the workpiece holder has a plurality of recording
10 areas each being provided by a magneto-optical material, or a photochromic material, the recording areas being located around the periphery of the workpiece as it is held by the workpiece holder, wherein the movable stage is adapted to move the workpiece holder so that on each
15 of the recording areas an image of a mark of the reticle is projected and thus recorded through the projection optical system; and

detecting means for detecting the images recorded on the recording areas of the workpiece holder and means
20 for determining, on the basis of obtained data, the co-ordinate of the pattern array on the workpiece for the step-and-repeat exposures of the workpiece.



2. Apparatus as claimed in claim 1, in which the recording areas are located on the workpiece holder.

3. Apparatus as claimed in claim 1, in which the
5 recording areas are located on the workpiece itself.

4. An apparatus according to any one of claims 1 to 3,
wherein there are four alignment patterns located
substantially equidistantly around the wafer holding
10 means.

5. An apparatus according to any previous claim, wherein
the surface of said recording layer is set at
substantially the same level as the surface of the
15 wafer.

6. An apparatus according to any previous claim,
wherein said recording layer is formed in a ring-like
shape on said wafer holding means.

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7. An apparatus according to any previous claim,
wherein said apparatus further includes an erasing means
for erasing an alignment pattern recorded on said
recording layer.

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8. An exposure apparatus or method substantially as described with reference to the drawings.

