

DESCRIPTION

EXPOSURE APPARATUS, EXPOSURE METHOD, AND DEVICE MANUFACTURING METHOD

5

TECHNICAL FIELD

The present invention relates to exposure apparatuses, exposure methods and device manufacturing methods, and more particularly to an exposure apparatus and an exposure method to form a pattern on an object with an energy beam, and a device manufacturing method that uses the exposure apparatus or the exposure method.

15 BACKGROUND ART

In a lithography process for manufacturing electron devices such as semiconductor devices (integrated circuits and the like) and liquid crystal display devices, an exposure apparatus such as a projection exposure apparatus by a step-and-repeat method (a so-called stepper) or a projection exposure apparatus by a step-and-scan method (a so-called scanning stepper (which is also called a scanner)) is mainly used.

In this type of exposure apparatus, in general, by using a laser interferometer, the position of a wafer stage that holds a substrate to be exposed such as a wafer or a glass plate (hereinafter, generically referred to as a wafer) is measured with the side surface of a barrel of a projection optical system serving as a reference, and position control

of the stage with respect to the projection optical system is performed using the measurement results (e.g. refer to Patent Literature 1). Accordingly, even if the position of the projection optical system finely varies due to vibration
5 or the like, the wafer stage can be made to follow the positional variation with high precision.

However, in the case where the laser interferometer is used to measure the position of the wafer stage with the barrel side surface of the projection optical system serving as a
10 reference, the optical path length of the measurement beam becomes as long as around several hundreds mm or more. Therefore, an error occurs in the measurement values in some cases due to temperature fluctuations (air fluctuations) of the atmosphere generated around the optical path of the
15 measurement beam, and this error becomes a factor of positional deviation of patterns formed on the wafer and overlay error between patterns of a plurality of layers that are layered and formed on the wafer.

Patent Literature 1: U.S. Patent Application
20 Publication No. 2007/0288121

DISCLOSURE OF INVENTION

MEANS FOR SOLVING THE PROBLEM

According to a first aspect of the present invention,
25 there is provided a first exposure apparatus that exposes an object with an energy beam via an optical member and forms a pattern on the object, the apparatus comprising: a movable body that moves along a predetermined plane, while holding the object; a holding member that holds the optical member;

and a first encoder that measures a distance between a predetermined reference position and the holding member in a first axis direction parallel to the plane.

With this apparatus, a distance in the first axis
5 direction from the reference position to the holding member that holds the optical member is measured by the first encoder. Accordingly, it becomes possible to measure the distance from the reference position to the optical member with high precision, even if the change in the atmosphere such as
10 temperature fluctuations occurs on the periphery of the first encoder and the holding member. Consequently, it becomes possible to move or position the movable body with high precision with the optical member serving as reference.

According to a second aspect of the present invention,
15 there is provided a second exposure apparatus that exposes an object with an energy beam via an optical member, the apparatus comprising: a movable body that can move within a predetermined plane, while holding the object; a holding member that holds the optical member; an encoder device that
20 has a scale arranged on one of the optical member and the holding member and a head arranged on the other, and measures positional information of the optical member in a direction parallel to the predetermined plane.

With this apparatus, the encoder device that has the
25 scale arranged on one of the optical member and the holding member and the head arranged on the other measures positional information of the optical member in a direction parallel to the predetermined plane. Accordingly, it becomes possible to measure positional information of the optical member with high

precision, even if the change in the atmosphere such as temperature fluctuations occurs on the periphery of the holding member.

According to a third aspect of the present invention,
5 there is provided a device manufacturing method, comprising:
a process of forming a pattern on an object by using one of
the first and second exposure apparatuses of the present
invention; and a process of developing the object on which
the pattern has been formed.

10 According to a fourth aspect of the present invention,
there is provided a first exposure method of exposing an object
with an energy beam via an optical member and forming a pattern
on the object, the method comprising: a first measurement
process of measuring a positional relation between the optical
15 member and a predetermined reference position within a
movement plane of a movable body that moves holding the object,
by using an encoder system.

With this method, the positional relation between the
optical member and the predetermined reference position
20 within a movement plane of the movable body that moves holding
the object is measured by using the encoder system.
Accordingly, it becomes possible to measure the positional
relation, with high precision, between the optical member and
the predetermined reference position within the movement
25 plane of the movable body. Consequently, it becomes possible
to move or position the movable body with high precision with
the optical member serving as reference.

According to a fifth aspect of the present invention,
there is provided a second exposure method of exposing an

object held by a movable body that can move within a predetermined plane, with an energy beam via an optical member, the method comprising: a process of, by using an encoder device that has a scale arranged on one of the optical member and
5 a holding member that holds the optical member and a head arranged on the other, measuring positional information of the optical member in a direction parallel to the predetermined plane.

With this method, by using the encoder device that has
10 the scale arranged on one of the optical member and the holding member and the head arranged on the other, positional information of the optical member in a direction parallel to the predetermined plane is measured. Accordingly, it becomes possible to measure the positional information of the optical
15 member with high precision, even if the change in the atmosphere such as temperature fluctuations occurs on the periphery of the holding member.

According to a sixth aspect of the present invention, there is provided a device manufacturing method, comprising:
20 a process of forming a pattern on an object by using one of the first and second exposure methods of the present invention; and a process of developing the object on which the pattern has been formed.

25 **BRIEF DESCRIPTION OF THE DRAWINGS**

FIG. 1 is a schematic view showing an exposure apparatus related to an embodiment.

FIG. 2A is a view used to explain an arrangement of head units and pickups, and FIG. 2B is a plan view showing a wafer

stage.

FIG. 3 is a perspective view showing a measurement mount.

FIG. 4 is a view used to explain an arrangement of the pickups and scales arranged on a barrel.

5 FIG. 5 is a block diagram showing a control system of the embodiment.

BEST MODE FOR CARRYING OUT THE INVENTION

10 An embodiment of the present invention is described below, with reference to FIGS. 1 to 5.

FIG. 1 shows a schematic configuration of an exposure apparatus 10 of the embodiment. Exposure apparatus 10 is a projection exposure apparatus by a step-and-scan method, which is a so-called scanning stepper. As is described later, 15 a projection optical system PL is arranged in the embodiment, and in the description below, the explanation is given assuming that an optical axis direction of projection optical system PL is a Z-axis direction, a direction in which a reticle and a wafer are relatively scanned within a plane orthogonal to 20 the Z-axis direction is a Y-axis direction, and a direction that is orthogonal to a Z-axis and a Y-axis is an X-axis direction, and rotation (inclination) directions about an X-axis, the Y-axis and the Z-axis are θ_x , θ_y and θ_z directions, respectively.

25 Exposure apparatus 10 is equipped with: an illumination unit IOP, a reticle stage RST that holds a reticle R, a projection unit PU including projection optical system PL, a wafer stage WST that moves within an XY plan while holding a wafer W, and their control system; and a column 34 that holds

projection unit PU; and the like.

Illumination unit IOP includes a light source and an illumination optical system, and irradiates a rectangular or circular arc illumination area that is defined by a field stop
5 (which is also called a masking blade or a reticle blind), which is placed inside illumination unit IOP, with an illumination light IL, and illuminates reticle R on which a circuit pattern is formed with uniform illuminance. As illumination light IL, an ArF excimer laser light (wavelength:
10 193nm) is used, as an example.

Reticle stage RST is placed above a reticle stage base 32a that constitutes a top board of column 34 (to be described later), and is supported by levitation above reticle stage base 32a by a magnetic levitation force that is generated by,
15 for example, a magnetic levitation type two-dimensional linear actuator that constitutes a reticle stage drive system 19R. And, on reticle stage RST, reticle R is fixed by, for example, vacuum suction or electrostatic suction.

Reticle stage RST is driven with a predetermined stroke
20 in the Y-axis direction (a lateral direction of the page surface of FIG. 1), and finely driven also in the X-axis direction (an orthogonal direction to the page surface of FIG. 1) and the θ_z direction, and further finely driven also in the Z-axis direction and inclination directions (the θ_x
25 direction and the θ_y direction) with respect to the XY plane, by reticle stage drive system 19R.

The position (including the rotation in the θ_z direction) of reticle stage RST (reticle R) within the XY plane is constantly detected at a resolution of, for example, around

0.25 to 1 nm with a reticle laser interferometer (hereinafter, referred to as a "reticle interferometer") 18R that irradiates a reflection surface fixed (or formed) on reticle stage RST with a laser beam. And, the position of reticle R in the Z-axis direction is measured by a reticle focus sensor RF (not shown in FIG. 1, refer to FIG. 5) that is composed of a multipoint focal position detecting system that is disclosed in, for example, U.S. Patent No. 5,448,332.

The measurement values of reticle interferometer 18R and reticle focus sensor RF are supplied to a main controller 11 (refer to FIG. 5). Main controller 11 drives reticle stage RST via reticle stage drive system 19R based on the supplied measurement values.

Projection unit PU referred to above has a barrel 40 having a cylindrical shape, and projection optical system PL composed of a plurality of optical elements held in barrel 40. In the embodiment, barrel 40 is a single barrel, but for example, barrel 40 can be configured layering a plurality of barrels each of which holds one or a plurality of optical element(s). In this case, it is preferable that the plurality of barrels are housed in a sealed member and the cleaning level of projection optical system PL is maintained at a high level.

As projection optical system PL described above, for example, a dioptric system that is composed of a plurality of optical elements (lens elements) that are disposed along the optical axis parallel to the Z-axis direction is used. Projection optical system PL is, for example, both-side telecentric and has a predetermined projection magnification (e.g. one-quarter, or one-fifth). Therefore, when the

illumination area described previously is illuminated by illumination light IL from illumination unit IOP, illumination light IL having passed through reticle R whose pattern surface is placed almost coincident with a first plane
5 (an object plane) of projection optical system PL forms a reduced image of a circuit pattern (a reduced image of a part of a circuit pattern) of reticle R within the illumination area onto an area (an exposure area) that is conjugate to the illumination area described above on wafer W, which is placed
10 on a second plane (an image plane) side of projection optical system PL and whose surface is coated with a resist (a photosensitive agent), via projection optical system PL.

Then, by moving reticle R in the scanning direction (the Y-axis direction) relative to the illumination area
15 (illumination light IL) and also moving wafer W in the scanning direction (the Y-axis direction) relative to the exposure area (illumination light IL) by synchronous drive of reticle stage RST and wafer stage WST, scanning exposure of one shot area (divided area) on wafer W is performed, and a pattern of reticle
20 R is transferred to the shot area. More specifically, in the embodiment, a pattern is generated on wafer W by illumination unit IOP, reticle R and projection optical system PL, and the pattern is formed on wafer W by exposure of a sensitive layer (resist layer) on wafer W with illumination light IL.

25 Column 34 includes a plurality (e.g. three in this case) of leg sections 32b (the leg section on the side of depth of the page surface is not shown) and reticle stage base 32a that is supported above a floor surface F by leg sections 32b. In the center portion of reticle stage base 32a, an opening 34a

having a rectangular shape in a planar view (when viewed from above) that penetrates in the vertical direction (the Z-axis direction) is formed.

Barrel 40 is, for example, a hollow member having a cylindrical shape with the Z-axis direction serving as its longitudinal direction that houses projection optical system PL, and a protruding section is formed in the center of the bottom wall. Inside the protruding section, an optical member that is located at the lower end of projection optical system PL is held, and in the center of the protruding section, an opening section that serves as a path of an illumination light is formed. This is not intended to be limiting, and the bottom wall of barrel 40 is configured of a plate member having a circular opening formed in the center portion, and a holding member that holds the optical member located at the lower end of projection optical system PL can be made to protrude from the circular opening.

Further, on the outer periphery at the position that is slightly lower than the center in the height direction of barrel 40, a flange FL having a ring shape is integrally arranged.

Flange FL is supported by a plurality, e.g. three of suspension support mechanisms 137 (however, the suspension support mechanisms on the side of depth of the page surface is not shown) whose one ends are fixed to the lower surface side of reticle stage base 32a, thus barrel 40 is supported in a suspended state below reticle stage base 32a. Each suspension support mechanism 137 includes, for example, a coil spring 136 that is a connecting member having a flexible

structure and a wire 135. Coil spring 136 oscillates like a pendulum in a direction perpendicular to the optical axis (the Z-axis) of projection optical system PL, and isolates vibration in the direction perpendicular to the optical axis of projection optical system PL (i.e. prevents the vibration of the floor from reaching to projection optical system PL). Further, coil spring 136 has a high vibration isolation performance also in a direction parallel to the optical axis. Incidentally, in the case where a barrel platform that supports projection unit PU is provided, the barrel platform can be supported in a suspended state by, for example, three suspension support mechanisms 137.

In the vicinity of the center portion of each of three leg sections 32b of column 34 in the Z-axis direction, a protruding section 134a is formed. Further, between each protruding section 134a and flange FLG of projection optical system PL, a drive mechanism 440 is arranged. Each drive mechanism 440 includes a voice coil motor that drives projection optical system PL in a radius direction of barrel 40 and a voice coil motor that drives projection optical system PL in the optical axis direction (the Z-axis direction). By three drive mechanisms 440 (the drive mechanism on the side of depth of the page surface of FIG. 1 is not shown) arranged between three protruding sections 134a and flange FL, projection optical system PL can be driven in directions of six degrees of freedom. In the embodiment, main controller 11 (refer to FIG. 5) controls the drive of the voice coil motors of each drive mechanism 440 so that projection optical system PL is in a stationary state with respect to column 34 and floor

surface F, based on, for example, acceleration information that is detected by an acceleration sensor (not shown) arranged on flange FLG of projection optical system PL.

Wafer stage WST is supported by levitation above a stage platform BS, which is placed below projection optical system PL and horizontally installed on floor surface F, via a plurality of noncontact bearings, for example, air bearings or the like arranged on its bottom surface. On wafer stage WST, wafer W is held by vacuum suction (or electrostatic suction) via a wafer holder (not shown).

The position of wafer stage WST is measured by the encoder system that is disclosed in, for example, U.S. Patent Application Publications No. 2007/0288121, No. 2008/0088843, No. 2006/0227309, and the like. In the embodiment, the encoder system has four linear encoders 70A to 70D (refer to FIG. 5), and as shown in FIG. 2A, four encoder head units 62A to 62D are placed on the lower surface of a measurement mount (holding member) 51 (the details will be described later on). Meanwhile, as shown in FIG. 2B, a pair of Y scales 44A and 44C with the Y-axis direction serving as their longitudinal directions and a pair of X scales 44B and 44D are fixed to the upper surface of wafer stage WST, respectively, so as to enclose wafer W. On the surface of each of scales 44A to 44D, a reflective type diffraction grating having a periodic direction in each longitudinal direction is formed.

The surface on the +Z side (the upper surface) of stage platform BS is processed so as to have a very high flatness degree, and serves as a reference surface (a guide surface) during movement of wafer stage WST. Wafer stage WST is driven

with a predetermined stroke in the Y-axis direction, and finely driven also in the X-axis direction and the θ_z direction, and further, finely driven also in the Z-axis direction and the inclination directions (the θ_x direction and the θ_y direction) with respect to the XY plane, by a wafer stage drive system 19W.

Measurement mount 51 is supported in a suspended state by flange FLG of projection optical system PL via a plurality (e.g. four, in this case) of support members 53 (however, the support member on the side of depth of the page surface is not shown). Each support member 53 is actually configured including a link member having a flexure section at both ends. Each flexure section has high rigidity in the longitudinal direction (the Z-axis direction) of the support member, and has low rigidity in the other directions of five degrees of freedom. Accordingly, measurement mount 51 is supported by the four support members while hardly generating a reaction force between measurement mount 51 and flange FLG.

As shown in a perspective view of FIG. 3, measurement mount 51 has a main section 52 having a circular plate shape, and four extending sections 53A, 53B, 53C and 53D each having a roughly square shape in a planar view that are arranged protruding in the +X direction, the +Y direction, the -X direction and the -Y direction, respectively, from main section 52.

Of main section 52, a section (an inner circular section) that excludes a rim section having a ring shape on the outer circumferential edge of the upper surface is a recessed section 52a whose inner bottom surface is lower than the rim section.

And, in the center of recessed section 52a, an annular surface area that is slightly lower than the inner bottom surface of recessed section 52a and is parallel to the upper surface is formed. The inner circumferential edge and the outer circumferential edge of the annular surface area and the rim section described previously are concentric. The inner circumferential edge of the surface area serves as the inner circumferential surface of a circular opening 52c. The surface area and the inner bottom surface of recessed section 52a are coupled by a taper slope. The surface area around circular opening 52c and the taper slope form a housing section 52b.

As shown in FIGS. 2A and 3, on the inner bottom surface of recessed section 52a of measurement mount 51, a pickup 54x and a pickup 54y are placed, which serve as sensor head sections of linear encoders 50x and 50y (refer to FIG. 5) to be described later on.

As shown in FIG. 2A, pickup 54x is placed on a straight line P_x , and is equipped with an x head 56x that irradiates a light upward (in +Z direction). Similarly, pickup 54y is placed on a straight line P_y , and is equipped with a y head 56y that irradiates a light upward.

On the lower surface (the surface on the -Z side) of projection unit PU, for example, on the lower surface of barrel 40, an x scale 58x and a y scale 58y are fixed facing pickups 54x and 54y respectively, as representatively shown by x scale 58x in FIG. 4.

As shown in the arrangement view of FIG. 2A, x scale 58x is placed on straight line P_x that is orthogonal to the optical

axis of projection optical system PL and is angled at 45 degrees with respect to the X-axis, with a direction parallel to straight line Px serving as its longitudinal direction, and y scale 58y is placed on straight line Py that is orthogonal to the optical axis of projection optical system PL and is angled at 45 degrees with respect to the Y-axis, with a direction parallel to straight line Py serving as its longitudinal direction. Further, on the lower surface (the surface on the -Z side) of each of scales 58x and 58y, a reflective type diffraction grating having a periodic direction in the longitudinal direction is formed.

Pickup 54x constitutes an x linear encoder 50x (refer to FIG. 5) by an optical method that detects the displacement of barrel 40 (projection optical system PL) in a direction parallel to straight line Px, which is caused by, for example, vibration, by using a reflected light (a diffracted light from the diffraction grating) obtained by irradiating x scale 58x fixed to the lower surface of barrel 40 with a light. Similarly, pickup 54y constitutes a y linear encoder 50y (refer to FIG. 5) by an optical method that detects the displacement of barrel 40 (projection optical system PL) in a direction parallel to straight line Py, by using a reflected light (a diffracted light from the diffraction grating) obtained by irradiating y scale 58y fixed to the lower surface of barrel 40 with a light.

In this case, in x linear encoder 50x and y linear encoder 50y, a diffraction interference type head, which has a configuration similar to the configuration of the encoder head that is enclosed in, for example, U.S. Patent No. 7,238,931,

U.S. Patent Application Publication No. 2007/0288121 and the like, is used as pickups 54x and 54y. However, in this embodiment, in pickups 54x and 54y, a light source and a photodetection system (including a photodetector) are placed
5 outside measurement mount 51 and only (a part of) an optical system including a polarization beam splitter that splits by polarization a light from the light source is placed on the inner bottom surface of recessed section 52a of measurement mount 51, that is, placed facing x scale 58x and y scale 58y.
10 More specifically, all sections of pickups 54x and 54y do not have to be arranged at measurement mount 51. In this case, between the light source and the photodetection system, and the optical system, lights and/or signals are transmitted/received by aerial transmission via an optical
15 fiber (not shown). In the description below, the optical system that is placed on the inner bottom surface of recessed section 52a of measurement mount 51 is referred to as a pickup. Incidentally, members that are placed outside measurement mount 51 are not limited to the light source and the
20 photodetection system, but can be only the light source, or can be only the light source and a photodetection element (sensor), or the like.

Further, as shown in FIG. 2A, on the lower surface (the -Z side surface) of measurement mount 51, four encoder head
25 units (hereinafter, also referred to as head units) 62A to 62D are placed so as to enclose the periphery of the lower end of projection optical system PL from four sides.

Head units 62A and 62C described above are respectively placed on the +X side and the -X side of projection unit PU,

with the X-axis direction serving as their longitudinal directions, symmetrically with respect to the optical axis of projection optical system PL. And, head units 62B and 62D are respectively placed on the +Y side and the -Y side of
5 projection unit PU, with the Y-axis direction serving as their longitudinal directions, symmetrically with respect to the optical axis of projection optical system PL.

As shown in FIG. 2A, head units 62A and 62C are each equipped with a plurality, in this case, five of Y heads 64
10 that are placed at a predetermined distance along the X-axis direction. Head unit 62A constitutes a multiple-lens, in this case, five-lens Y linear encoder 70A (refer to FIG. 5) equipped with a plurality of Y heads 64 that measures the position in the Y-axis direction (Y-position) of wafer stage WST, using
15 Y scale 44A described previously on wafer stage WST. Similarly, head unit 62C constitutes a five-lens Y linear encoder 70C (refer to FIG. 5) equipped with five Y heads 64 that measures the Y-position of wafer stage WST, using Y scale 44C described previously.

20 Further, as shown in FIG. 2A, head units 62B and 62D are each equipped with a plurality, in this case, five of X heads 66 that are placed at a predetermined distance along the Y-axis direction. Head unit 62B constitutes a multiple-lens, in this case, five-lens X linear encoder 70B (refer to FIG. 5) equipped
25 with a plurality of X heads 66 that measures the position in the X-axis direction (X-position) of wafer stage WST, using X scale 44B described previously. Similarly, head unit 62D constitutes a five-lens X linear encoder 70D (refer to FIG. 5) equipped with five X heads 66 that measures the X-position

of wafer stage WST, using X scale 44D described previously.

Measurement mount 51 having the configuration as described above is supported in a suspended state with the above-described four support members 53 (however, the support member on the side of depth of the page surface is not shown) whose upper ends are fixed (connected) to flange FLG and whose lower ends are fixed (connected) to extending sections 53A to 53D respectively, and is placed at a position a predetermined distance lower (in the -Z direction) than the lower surface of barrel 40. In this suspended support state, as shown in FIG. 4, the protruding section of the lower end of barrel 40 is housed in housing section 52b formed at measurement mount 51. Further, as shown in FIG. 4, the lower surface of barrel 40 and the inner bottom surface of recessed section 52a face each other via a predetermined gap, x head 56x of pickup 54x and x scale 58x placed on the lower surface of barrel 40 face each other, and y head 56y of pickup 54y and y scale 58y placed on the lower surface of barrel 40 face each other.

Furthermore, an alignment system ALG, a wafer focus sensor WF, and the like (refer to FIG. 5) are attached to measurement mount 51. As alignment system ALG, a sensor by an image processing method can be used, and this sensor by an image processing method is disclosed in, for example, Kokai (Japanese Unexamined Patent Application Publication) No. 04-065603 (the corresponding U.S. Patent No. 5,493,403). Further, as wafer focus sensor WF, the wafer focus sensor that is disclosed in, for example, Kokai (Japanese Unexamined Patent Application Publication) No. 06-283403 (the

corresponding U.S. Patent No. 5,448,332) can be used.

Incidentally, in the embodiment, since the above-described scales 58x and 58y and head units 62A to 62D, and the like are arranged at measurement mount 51, measurement
5 mount 51 can also be called a metrology frame or the like. Further, in the embodiment, not only scales 58x and 58y but also head units 62A to 62D, alignment system ALG and wafer focus sensor WF are arranged at measurement mount 51, but this is not intended to be limiting, and for example, at least either
10 one of head units 62A to 62D, alignment system ALG or wafer focus sensor WF can be arranged at another member that is separate from measurement mount 51.

FIG. 5 shows the control system of exposure apparatus 10 of the embodiment in a block diagram. The control system
15 shown in FIG. 5 includes a so-called microcomputer (or workstation), which is composed of a CPU (Central Processing Unit), an ROM (Read Only Memory), an RAM (Random Access Memory), and the like, and is mainly configured by main controller 11 that performs overall control of the entire apparatus.

20 In exposure apparatus 10 having the configuration as described above, wafer stage WST that holds wafer W is located below measurement mount 51 during the exposure operation, Y scales 44A and 44C placed on the upper surface of wafer stage WST face head units 62A and 62C respectively, and X scales
25 44B and 44D face head units 62B and 62D respectively. And, the position of wafer stage WST in the Y-axis direction is measured by head units 62A and 62C facing Y scales 44A and 44C (Y linear encoders 70A and 70C) and the position of wafer stage WST in the X-axis direction is measured by head units

62B and 62D facing X scales 44B and 44D (X linear encoders 70B and 70D). Further, at the same time, by pickup 54x that faces x scale 58x placed on the lower surface of barrel 40 (y linear encoder 50x) and pickup 54y that faces y scale 58y placed on the lower surface of barrel 40 (y linear encoder 50y), the displacement of barrel 40 in directions parallel to straight line Px and straight line Py, more specifically, the position of barrel 40 within the XY plane is measured. Then, main controller 11 monitors measurement results of Y linear encoders 70A and 70C and X linear encoders 70B and 70D, and measurement results of x linear encoder 50x and y linear encoder 50y, and moves wafer stage WST within the XY plane with barrel 40 serving as a reference.

As is described above, according to exposure apparatus 10 of the embodiment, the displacement of barrel 40 within the XY plane during the exposure operation is measured by pickup 54x placed on measurement mount 51 that faces scale 58x placed on the lower surface of barrel 40 (x linear encoder 50x) and pickup 54y placed on measurement mount 51 that faces scale 58y placed on the lower surface of barrel 40 (y linear encoder 50y). Accordingly, even if the position of barrel 40 within the XY plane slightly varies due to vibration caused by the movement of wafer stage WST and the like, the displacement can be measured with high precision, and consequently, position control of wafer stage WST with the optical axis of projection optical system PL held by barrel 40 serving as a reference can be performed with high precision.

Further, a light (hereinafter, referred to as a measurement light) emitted from pickup 54x or 54y is reflected

off X scale 58x or y scale 58y, and propagates back and forth between pickup 54x or 54y and x scale 58x or y scale 58y fixed to barrel 40, and the path of the measurement light is shortened to a level that can be ignored compared with the path of the measurement light in the case of an interferometer. Accordingly, even if air fluctuations occur on the periphery or the like of barrel 40 during exposure, the short-term stability of the measurement values of x linear encoder 50x and y linear encoder 50y can be significantly improved, compared with the case of using the interferometer.

Further, in the embodiment, pickups 54x and 54y that emit the measurement light used for measurement of displacement of barrel 40, and head units 62A to 62D that measure the position of wafer stage WST are both placed at measurement mount 51. Therefore, the positional relation between pickups 54x and 54y, and head units 62A to 62D is maintained constant, and accordingly measurement error that occurs between X linear encoders 70B and 70D and Y linear encoders 70A and 70C that perform measurement with respect to wafer stage WST, and x linear encoder 50x and y linear encoder 50y that perform measurement with respect to barrel 40 can be reduced.

Incidentally, in the embodiment above, the displacement of barrel 40 in directions parallel to straight line Px and straight line Py that are angled at 45 degrees with respect to the X-axis and the Y-axis is measured by x linear encoder 50x and y linear encoder 50y, but this is not intended to be limiting, and the displacement of barrel 40 in the X-axis direction and the Y-axis direction can be measured using the encoders, or the displacement of barrel 40 within the XY plane

can be measured by measuring the displacement in arbitrary two different axis directions. More specifically, the longitudinal directions (the measurement directions, the periodic directions/arrangement directions of the diffraction gratings) of scales 58x and 58y are not limited to directions parallel to straight lines Px and Py but may be arbitrary directions.

Further, in the embodiment above, only (a part of) the optical system is placed at measurement mount 51 in order to avoid a heat source, but in the case where the influence of heat can be excluded or the influence of heat does not have to be considered, the light source and/or the photodetection system (including the photodetector) can also be placed at measurement mount 51.

Further, in the embodiment above, pickup 54x of x linear encoder 50x and pickup 54y of y linear encoder 50y are attached to measurement mount 51, but this is not intended to be limiting, and pickups 54x and 54y are attached to barrel 40 and the displacement of barrel 40 with respect to measurement mount 51 can be measured by using scales 58x and 58y attached to measurement mount 51.

Further, in the description above, pickups 54x and 54y or scales 58x and 58y are attached to the lower end surface of projection unit PU (barrel 40), but pickups 54x and 54y or scales 58x and 58y can be fixed to other sections than the lower end surface of projection unit PU (barrel 40).

Further, in the embodiment above, x linear encoder 50x and y linear encoder 50y by the optical method are used for displacement measurement of barrel 40, but the method is not

limited thereto, and for example, an encoder by an electromagnetic induction method can also be used.

Further, in the embodiment above, the displacement of barrel 40 is measured by using x linear encoder 50x and y linear encoder 50y respectively equipped with pickups 54x and 54y that receive reflected lights obtained by irradiating the scales with lights, but this is not intended to be limiting, and as an encoder to measure the displacement of barrel 40, for example, an encoder that measures the displacement using transmitted lights that have been transmitted through scales 58x and 58y can be employed.

Further, the encoder can be configured capable of measuring the displacement of barrel 40 not only in two arbitrary different axis directions such as the X-axis and the Y-axis, but also, for example, in another direction (such as the θz direction).

Incidentally, in the embodiment above, projection unit PU (projection optical system PL) is supported in a suspended state below reticle stage base 32a by three suspension support mechanisms 137 via flange FLG, but this is not intended to be limiting, and projection unit PU (projection optical system PL) can be supported by the barrel platform that is horizontally supported on the floor surface via the vibration isolation device. In this case, measurement mount 51 can also be supported in a suspended state by the barrel platform. The point is that the positional relation between projection unit PU (projection optical system PL) and the reference position within the XY plane should be measurable by the linear encoders. Further, at least either one of head units 62A to 62D, alignment

system ALG or wafer focus sensor WF described earlier can be arranged on the barrel platform independently from measurement mount 51.

Further, in the embodiment, the position measurement of wafer stage WST is performed using the encoder system that includes X linear encoders 70B and 70D and Y linear encoders 70A and 70C, but the method of the position measurement of wafer stage WST is not limited thereto. For example, the position measurement of wafer stage WST can be performed by an interferometer system or an interferometer system and an encoder system. In the interferometer system, the position measurement of the wafer stage does not have to be performed with a projection optical system PL as a reference, and therefore the reflection surface of the measurement beam of the interferometer system does not have to be arranged at projection optical system PL. Incidentally, the exposure apparatus equipped with both the interferometer system and the encoder system is disclosed in, for example, U.S. Patent Application Publications No. 2007/0288121 and No. 2008/0088843, and the like.

Further, in the embodiment above, the case has been exemplified where the encoder system is employed in which the grating sections (Y scales and X scales) are arranged on the wafer table (wafer stage) and the X heads and Y heads are placed outside the wafer stage so as to face the grating sections, but this is not intended to be limiting, and as is disclosed in, for example, U.S. Patent Application Publication No. 2006/0227309 and the like, the encoder heads are arranged on the wafer stage and the grating sections (e.g. grating sections

of a two-dimensional grating, or of one-dimensional gratings placed two-dimensionally) are placed outside the wafer stage so as to face the encoder heads. In this case, Z heads that measure the position of the wafer table in the Z-axis direction
5 are also arranged on the wafer stage and the surface of the grating section can be used as a reflection surface to which the measurement beams of the Z heads are irradiated. In such a case, a single head having a function of the encoder head and the Z head can also be used. Further, the grating sections
10 (scales) can be supported by the measurement mount or the barrel platform described earlier, as an example.

Further, in the embodiment above, the case has been described where the present invention is applied to the scanning stepper, but this is not intended to be limiting,
15 and the present invention can also be applied to a static exposure apparatus such as a stepper. Further, the present invention can also be applied to a projection exposure apparatus by a step-and-stitch method that synthesizes a shot area and a shot area.

20 Further, the magnification of the projection optical system in the exposure apparatus of the embodiment above is not only a reduction system, but also can be either an equal magnifying system or a magnifying system, and projection optical system PL is not only a dioptric system, but also can
25 be either a catoptric system or a catadioptric system, and in addition, the projected image can be either an inverted image or an upright image.

Further, illumination light IL is not limited to the ArF excimer laser light (wavelength: 193nm), but can be an

ultraviolet light such as a KrF excimer laser light (wavelength: 248nm), or a vacuum ultraviolet light such as an F₂ laser light (wavelength: 157nm). Besides the lights referred to above, an emission line in an ultraviolet range such as a g-line (wavelength: 436nm) or an i-line (wavelength: 365nm) that is generated by an extra-high pressure mercury can also be used as illumination light IL. Further, as is disclosed in, for example, U.S. Patent No. 7,023,610, a harmonic wave, which is obtained by amplifying a single-wavelength laser beam in the infrared or visible range emitted by a DFB semiconductor laser or fiber laser, with a fiber amplifier doped with, for example, erbium (or both erbium and ytterbium), and by converting the wavelength into ultraviolet light using a nonlinear optical crystal, can also be used, as vacuum ultraviolet light.

Further, in the embodiment above, illumination light IL of the exposure apparatus is not limited to the light having a wavelength more than or equal to 100nm, and it is needless to say that the light having a wavelength less than 100nm can be used. For example, in recent years, in order to expose a pattern less than or equal to 70nm, an EUV (Extreme Ultraviolet) exposure apparatus that makes an SOR or a plasma laser as a light source generate an EUV light in a soft X-ray range (e.g. a wavelength range from 5 to 15 nm), and uses a total reflection reduction optical system designed under the exposure wavelength (e.g. 13.5nm) and the reflective mask has been developed. In this apparatus, the arrangement in which scanning exposure is performed by synchronously scanning a mask and a wafer using a circular arc illumination can be

considered, and therefore, the present invention can also be applied to such an exposure apparatus. In addition, the present invention can also be applied to an exposure apparatus that uses charged particle beams such as an electron beam or
5 an ion beam.

Moreover, the present invention can also be applied to a liquid immersion exposure apparatus such as the liquid immersion exposure apparatus in which a space between projection optical system PL and a wafer is filled with a liquid
10 (e.g. pure water or the like), which is disclosed in, for example, the pamphlet of International Publication No. 99/49504 and the like.

Further, in the embodiment above, a transmissive type mask (reticle), which is a transmissive substrate on which
15 a predetermined light shielding pattern (or a phase pattern or a light attenuation pattern) is formed, is used. Instead of this reticle, however, as is disclosed in, for example, U.S. Patent No. 6,778,257, an electron mask (a variable shaped mask) on which a light-transmitting pattern, a reflection
20 pattern, or an emission pattern is formed according to electronic data of the pattern that is to be exposed can also be used.

Further, the present invention can also be applied to an exposure apparatus (lithography system) that forms
25 line-and-space patterns on wafer W by forming interference fringes on wafer W, as is disclosed in, for example, the pamphlet of International Publication No. 2001/035168.

Moreover, the present invention can also be applied to an exposure apparatus that synthesizes two reticle patterns

on a wafer via a projection optical system and almost simultaneously performs double exposure of one shot area on the wafer by one scanning exposure, as is disclosed in, for example, U.S. Patent No. 6,611,316.

5 Incidentally, an object on which a pattern is to be formed (an object subject to exposure to which an energy beam is irradiated) in the embodiment above is not limited to a wafer, but may be another object such as a glass plate, a ceramic substrate, a film member, or a mask blank.

10 The use of the exposure apparatus is not limited to the exposure apparatus for manufacturing semiconductor devices, but the present invention can also be widely applied, for example, to an exposure apparatus for liquid crystal display devices that transfers a liquid crystal display device pattern
15 onto a rectangular glass plate, and an exposure apparatus for producing organic ELs, thin-film magnetic heads, imaging devices (such as CCDs), micromachines, DNA chips, and the like. Further, the present invention can be applied not only to an exposure apparatus for producing microdevices such as
20 semiconductor devices, but can also be applied to an exposure apparatus that transfers a circuit pattern onto a glass substrate or silicon wafer to produce a reticle or a mask used in a light exposure apparatus, an EUV exposure apparatus, an X-ray exposure apparatus, an electron-beam exposure apparatus,
25 and the like.

 Incidentally, the above disclosures of all the publications, the pamphlets of the International Publications, and specifications of the U.S. Patent Application Publications and the U.S. Patents that are cited in the

description above and related to exposure apparatuses and the like are each incorporated herein by reference.

Incidentally, semiconductor devices are manufactured through the following steps: a step where the
5 function/performance design of a device is performed, a step where a reticle is manufactured based on this design step; a step where a wafer is manufactured from silicon materials; a lithography step where a pattern of the mask (reticle) is transferred onto the wafer by the exposure apparatus (pattern
10 formation apparatus) of the embodiment described previously; a development step where the exposed wafer is developed; an etching step where an exposed member of an area other than the area where resist remains is removed by etching; a resist removing step where the resist that is no longer necessary
15 when the etching is completed is removed; a device assembly step (including a dicing process, a bonding process, and a packaging process); an inspection step; and the like. In this case, since the exposure apparatus of the embodiment above is used in the lithography step, the devices with high
20 integration can be manufactured with good yield.

INDUSTRIAL APPLICABILITY

As is described above, the exposure apparatus, the exposure method and the device manufacturing method of the
25 present invention are suitable for manufacturing electron devices such as semiconductor devices and liquid crystal display devices.

CLAIMS

1. An exposure apparatus that exposes a substrate via a projection optical system, the apparatus comprising:

a frame member that supports the projection optical system;

a substrate stage that is disposed below the projection optical system supported by the frame member, and holds the substrate;

a drive device that drives the substrate stage;

an encoder device that measures positional information of the projection optical system supported by the frame member;

an encoder system that measures positional information of the substrate stage;

and

a controller that controls driving of the substrate stage by the drive device, based on the positional information measured with the encoder system, wherein

the encoder device has a head section that is placed facing a first grating member in which a reflective grating is formed, and the encoder device irradiates the first grating member with a first measurement beam via the head section, one of the first grating member and the head section being provided at a part of a lower end surface of the projection optical system, the other of the first grating member and the head section being provided at a holding member, and the holding member being supported, in a suspended manner from the frame member, at a position lower than the one of the first grating member and the head section,

the encoder system has a plurality of heads that each irradiate a second grating member with a second measurement beam, the second grating member being different from the first grating member, in the second grating member a reflective grating being formed, one

of the second grating member and the plurality of heads being provided at the substrate stage, and the other of the second grating member and the plurality of heads being supported by the frame member, independently from the encoder device, and

the first grating member is provided without protruding outward from the lower end surface in a direction parallel to a predetermined plane, the predetermined plane being orthogonal to an optical axis of the projection optical system.

2. The exposure apparatus according to Claim 1, wherein
the other of the second grating member and the plurality of heads is provided at another member that is different from the holding member.

3. The exposure apparatus according to Claim 1 or 2, wherein
the holding member is supported in a suspended manner from the frame member, by a plurality of support members that each have a flexure section.

4. An exposure apparatus that exposes a substrate via a projection optical system, the apparatus comprising:

a frame member that supports the projection optical system;

a substrate stage that is disposed below the projection optical system supported by the frame member, and holds the substrate;

a drive device that drives the substrate stage;

a holding member that is supported in a suspended manner from the frame member;

an encoder device that measures positional information of the projection

optical system supported by the frame member;

an encoder system that measures positional information of the substrate stage;

and

a controller that controls driving of the substrate stage by the drive device, based on the positional information measured with the encoder system, wherein

the encoder device has a head section that is placed facing a first grating member in which a reflective grating is formed, and the encoder device irradiates the first grating member with a first measurement beam via the head section, one of the first grating member and the head section being provided at the projection optical system, and the other of the first grating member and the head section being provided at the holding member, and

the encoder system has a plurality of heads that each irradiate a second grating member with a second measurement beam, the second grating member being different from the first grating member, in the second grating member a reflective grating being formed, one of the second grating member and the plurality of heads being provided at the substrate stage, and the other of the second grating member and the plurality of heads being provided at the holding member.

5. The exposure apparatus according to Claim 4, wherein

the holding member is supported in a suspended manner from the frame member, by a plurality of support members that each have a flexure section.

6. The exposure apparatus according to any one of Claims 1 to 5, wherein

in the encoder device, both of the first grating member and the head section are disposed higher than a lower surface of the projection optical system, in a direction that is

substantially parallel to an optical axis of the projection optical system.

7. The exposure apparatus according to any one of Claims 1 to 6, wherein the projection optical system has a flange section, and is supported by the frame member via the flange section, and one of the first grating member and the head section is provided lower than the flange section of the projection optical system.

8. The exposure apparatus according to any one of Claims 1 to 7, wherein one of the first grating member and the head section is provided at a part of a lower end surface of the projection optical system, and the other of the first grating member and the head section is provided lower than the one of the first grating member and the head section.

9. The exposure apparatus according to Claim 8, wherein the first grating member is provided at the projection optical system without protruding outward from the lower end surface in a direction parallel to a predetermined plane, the predetermined plane being orthogonal to an optical axis of the projection optical system.

10. The exposure apparatus according to any one of Claims 1 to 9, wherein the first grating member has a plurality of first scales in each of which a grating is formed, and the encoder device has a plurality of heads sections that are placed facing the plurality of first scales, respectively.

11. The exposure apparatus according to any one of Claims 1 to 10, wherein
the encoder device has a light source and a detector, and at least one of the light source and the detector is connected to the head section via an optical fiber, the light source generating the first measurement beam, and the detector receiving the first measurement beam reflected off the first grating member.
12. The exposure apparatus according to any one of Claims 1 to 11, wherein
the second grating member is disposed substantially parallel to a predetermined plane that is orthogonal to an optical axis of the projection optical system, and
the encoder system measures positional information of the substrate stage in a direction parallel to the predetermined plane and a direction orthogonal to the predetermined plane.
13. The exposure apparatus according to Claim 12, wherein
in the encoder system, the second grating member is provided at the holding member and the plurality of heads are provided at the substrate stage, and the encoder system irradiates the second grating member from below with the second measurement beam.
14. The exposure apparatus according to Claim 12 or 13, wherein
the second grating member has a plurality of second scales in each of which a grating is formed, and
the encoder system irradiates each of the plurality of second scales with the second measurement beam via the plurality of heads.

15. A device manufacturing method, including:

exposing a substrate using the exposure apparatus according to any one of

Claims 1 to 14; and

developing the substrate that has been exposed.