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(54) EXPOSURE APPARATUS, EXPOSURE METHOD, AND DEVICE MANUFACTURING METHOD

(57) An exposure apparatus in equipped with an encoder system which measures positional information of a wafer stage (WST1) by irradiating a measurement beam using four heads (60_1 to 60_4) installed on the wafer stage (WST1) on a scale plate (21) which covers the movement range of the wafer stage (WST1) except for the area right under a projection optical system (PL). Placement distances (A, B) of the heads (60_1 to 60_4) here are each set to be larger than width (a_i, b_i) of the opening of the scale plates (21), respectively. This allows the positional information of the wafer stage to be measured, by switching and using the three heads facing the scale plate out of the four heads according to the position of the wafer stage.

Fig. 1

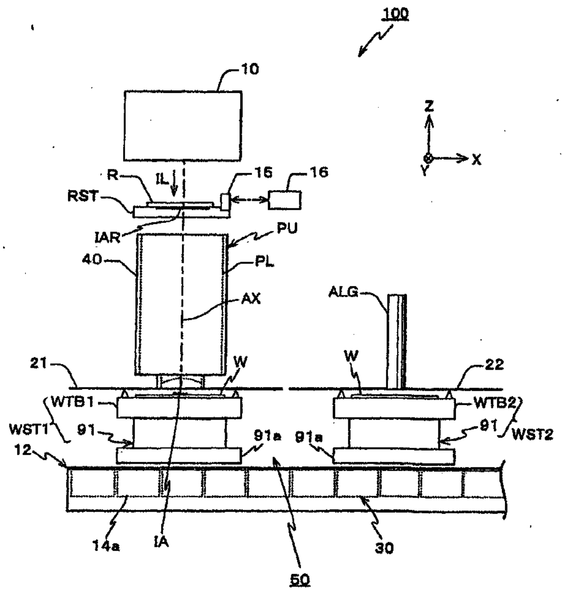

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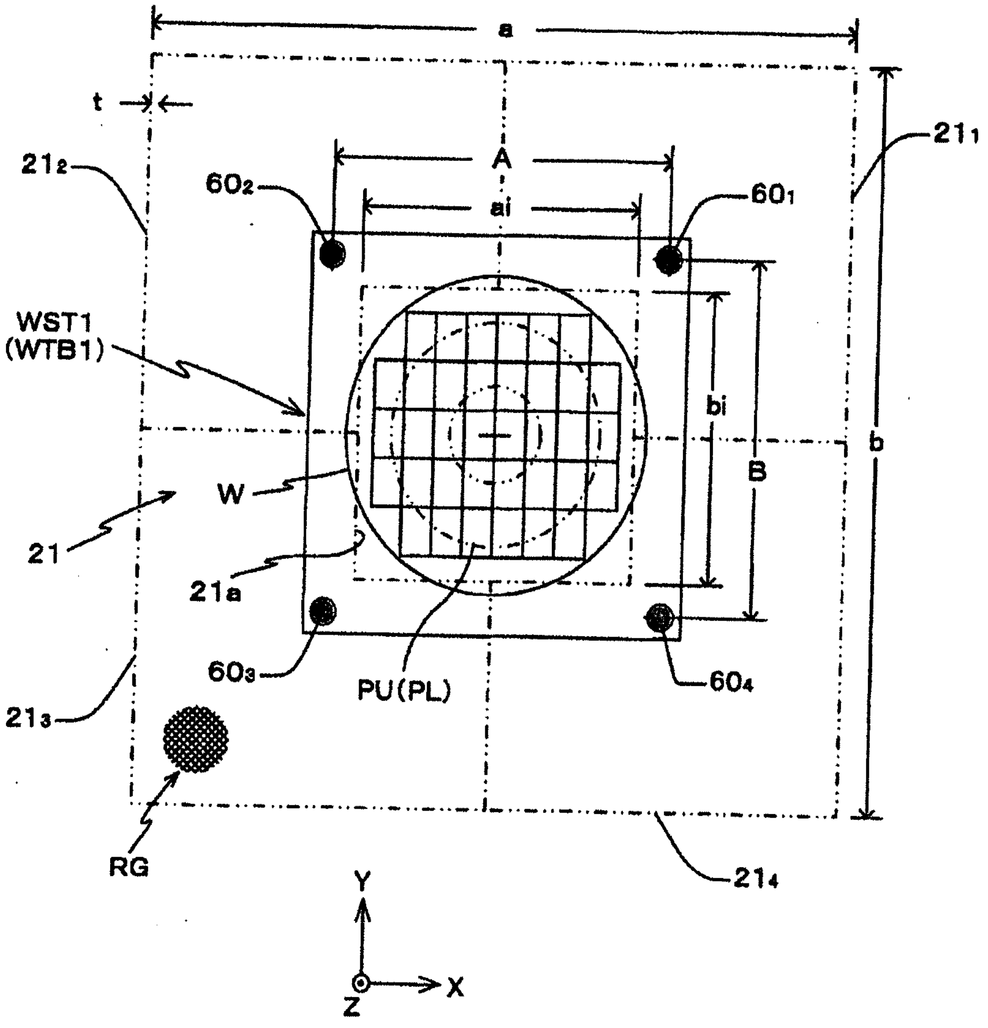
Fig. 2


a
t
21_1
21_2
A
ai
60_2
60_1
WST1
(WTB1)
bi
b
B
W
21
21a
60_3
60_4
PU(PL)
21_3
RG
21_4
Y
X
Z

Description

Technical Field

[0001] The present invention relates to exposure apparatuses, exposure methods, and device manufacturing methods, and more particularly to an exposure apparatus and an exposure method used in a lithography process to manufacture microdevices such as a semiconductor device, and a device manufacturing method using the exposure method.

Background Art

[0002] Conventionally, in a lithography process for manufacturing electron devices (microdevices) such as semiconductor devices (such as integrated circuits) and liquid crystal display devices, exposure apparatuses 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.

[0003] In these types of exposure apparatuses, with finer device patterns due to higher integration of semiconductor devices, requirements for high overlay accuracy (alignment accuracy) is increasing. Therefore, requirements for higher accuracy is increasing, also in position measurement of substrates such as a wafer or a glass plate and the like on which a pattern is formed.

[0004] As an apparatus to meet such requirements, for example, in PTL 1, an exposure apparatus is proposed which is equipped with a position measurement system using a plurality of encoder type sensors (encoder heads) installed on a substrate table. In this exposure apparatus, the encoder head irradiates a measurement beam on a scale which is placed facing a substrate table, and measures the position of the substrate table by receiving a return beam from the scale.

[0005] However, in the exposure apparatus which is equipped with the position measurement system described in PTL 1, as for the actual operation, the encoder head facing the scale has to be switched from a plurality of encoder heads according to the position of the substrate table. Furthermore, when switching the encoder head which is to be used, continuity of the position measurement results of the substrate table also has to be secured.

Citation List

Patent Literature

[0006] [PTL 1] U.S. Patent Application Publication No. 2006/0227309

Summary of Invention

[0007] The present invention was made under the circumstances described above, and according to a first aspect, there is provided a first exposure apparatus which sequentially exposes an energy beam on a plurality of divided areas placed in a shape of a matrix on an object, and forms a pattern on each of the plurality of divided areas, the apparatus comprising: a movable body which holds the object and moves along a predetermined plane; a position measurement system which has a plurality of heads provided on the movable body, and of the plurality of heads, obtains a positional information of the movable body, based on measurement results of a predetermined number of heads which irradiate a measurement beam on a measurement plane that has an opening partially and is placed facing the movable body and roughly parallel to the predetermined plane, receive a return beam from the measurement plane, and measure a position of the movable body in each measurement direction; and a control system which drives the movable body based on the positional information obtained by the position measurement system, and also switches at least one of the predetermined number of heads used to compute a positional information of the movable body according to a position of the movable body to a different head, wherein of the plurality of heads, a separation distance of two heads set apart in a first direction within the predetermined plane is larger than a width of the opening in the first direction.

[0008] According to this apparatus, it becomes possible to measure the positional information of a movable body by switching and using encoder heads facing a scale from a plurality of encoder heads according to the position of the movable body.

[0009] According to a second aspect of the present invention, there is provided a second exposure apparatus which sequentially exposes an energy beam on a plurality of divided areas on an object, and forms a pattern on each of the plurality of divided areas on the object, the apparatus comprising: a movable body which holds the object and moves along a predetermined plane; a position measurement system which has a plurality of heads provided on the movable body, and of the plurality of heads, irradiates a measurement beam on a measurement plane having a measurement non-effective area in part of the measurement plane which is placed facing the movable body and roughly parallel to the predetermined plane, receives a return beam from the measurement plane, and obtains a positional information of the movable body based on measurement results of a predetermined number of heads which measure a position of the movable body in each measurement direction; and a control system which drives the movable body based on the positional information obtained by the position measurement system, while switching a head to be used to compute the positional information of the movable body, wherein of the plurality of heads, a separation distance of two heads set apart in a predetermined direction within the predetermined plane is decided, taking into consideration a size of the measurement non-effective area in the predetermined direction.

[0010] According to this apparatus, because the separation distance between the two heads is decided adequately taking into consideration the size of a measurement non-effective area in a predetermined direction, the positional information of the movable body can be measured without switching the heads while the movable body performs a constant speed movement in a predetermined direction to form a pattern on a divided area subject to formation on the object. Accordingly, it becomes possible to form a pattern on the object with good precision.

[0011] According to a third aspect of the present invention, there is provided a third exposure apparatus which sequentially exposes an energy beam on a plurality of divided areas placed in a shape of a matrix on an object, and forms a pattern on each of the plurality of divided areas, the apparatus comprising: a movable body which holds the object and moves along a predetermined plane; a position measurement system which has a plurality of heads provided on the movable body, and of the plurality of heads, irradiates a measurement beam on a measurement plane having an opening in part of the measurement plane which is placed facing the movable body and roughly parallel to the predetermined plane, receives a return beam from the measurement plane, and obtains a positional information of the movable body based on measurement results of a predetermined number of heads which measure a position of the movable body in each measurement direction; and a control system which drives the movable body based on positional information obtained by the position measurement system, and also switches at least one of the predetermined number of heads used to compute a positional information of the movable body according to a position of the movable body to a different head, wherein after a constant speed movement on the movable body is performed in a first area where heads included in a first head group and a second head group which has at least one different head of the plurality of heads face the measurement plane, in a first direction of the predetermined plane to form the pattern in a divided area subject to formation of the plurality of divided areas based on the positional information of the movable body which is obtained based on measurement results of the first head group, heads used to compute positional information of the movable body are switched to the second head group before the movable body moves from the first area to a second area where only the heads included in the second head group face the measurement plane.

[0012] According to this apparatus, the positional information of the movable body can be measured without switching the heads while the movable body performs a constant speed movement in the first direction to form a pattern on a divided area subject to formation on the object. Accordingly, it becomes possible to form a pattern on the object with good precision.

[0013] According to a fourth aspect of the present invention, there is provided a first exposure method in which a plurality of divided areas placed in a shape of a matrix on an object is sequentially exposed an energy beam, and a pattern is formed on each of the plurality of divided areas, the method comprising: obtaining a positional information of the movable body, based on measurement results of a predetermined number of heads of the plurality of heads provided on the movable body which moves along a predetermined plane holding the object, by irradiating a measurement beam on a measurement plane having an opening in part of the measurement plane which is placed facing the movable body and roughly parallel to the predetermined plane, receiving a return beam from the measurement plane, and measuring a position of the movable body in each measurement direction; moving the movable body at a constant speed in the first direction in the predetermined plane to form the pattern in a divided area subject to formation of the plurality of divided areas, based on the positional information; and after the movable body is moved at a constant speed, switching at least one of the predetermined number of heads used to compute a positional information of the movable body according to a position of the movable body to a different head.

[0014] According to this method, the positional information of the movable body can be measured without switching the heads while the movable body performs a constant speed movement in the first direction to form a pattern on a divided area subject to formation on the object. Accordingly, it becomes possible to form a pattern on the object with good precision.

[0015] According to a fifth aspect of the present invention, there is provided a second exposure method in which a plurality of divided areas placed in a shape of a matrix on an object is sequentially exposed by an energy beam, and a pattern is formed on each of the plurality of divided areas, the method comprising: obtaining a positional information of the movable body, based on measurement results of a predetermined number of heads of the plurality of heads provided on the movable body which moves along a predetermined plane holding the object, by irradiating a measurement beam on a measurement plane having an opening in part of the measurement plane which is placed facing the movable body and roughly parallel to the predetermined plane, receiving a return beam from the measurement plane, and measuring a position of the movable body in each measurement direction; stepping and driving the movable body toward a starting point of a constant speed drive to form the pattern in a divided area subject to formation of the plurality of divided areas, based on the positional information obtained; and switching at least one of the predetermined number of heads used to compute a positional information of the movable body according to a position of the movable body to a different head before the movable body is moved at a constant speed in the first direction to form the pattern in the divided area subject to formation, after the stepping and driving.

[0016] According to this method, the positional information of the movable body can be measured without switching the heads while the movable body performs a constant speed movement in the first direction to form a pattern on a divided area subject to formation on the object.

[0017] According to a sixth aspect of the present invention, there is provided a third exposure method in which a plurality of divided areas placed in a shape of a matrix on an object is sequentially exposed by an energy beam, and a pattern is formed on each of the plurality of divided areas, the method comprising: obtaining positional information of the movable body within a first area where of a plurality of heads provided on a movable body which moves along a predetermined plane holding the object, heads included in a first head group and a second head group which has at least one head different from the first head group face a measurement plane which is provided roughly parallel to the predetermined plane, based on measurement results of the first head group, and performing a constant speed drive of the movable body in a first direction of the predetermined plane to form the pattern on a divided area subject to formation of the plurality of divided areas, based on the positional information; and switching heads to be used to compute the positional information to the second heads group after the constant speed movement, before the movable body moves from the first area to a second area where heads included only in the second group face the measurement plane.

[0018] According to this method, the positional information of the movable body can be measured without switching the heads while the movable body performs a constant speed movement in the first direction to form a pattern on a divided area subject to formation on the object. Accordingly, it becomes possible to form a pattern on the object with good precision.

[0019] According to a seventh aspect of the present invention, there is provided a fourth exposure method in which a plurality of divided areas placed in a shape of a matrix on an object is sequentially exposed by an energy beam, and a pattern is formed on each of the plurality of divided areas, the method comprising: obtaining positional information of the movable body within a first area where of a plurality of heads provided on a movable body which moves along a predetermined plane holding the object, heads included in a first head group and a second head group which has at least one head different from the first head group face a measurement plane which is provided roughly parallel to the predetermined plane, based on measurement results of the first head group, and performing a step drive of the movable body toward a starting position of the constant speed movement to form the pattern on a divided area subject to formation of the plurality of divided areas, based on the positional information; and switching heads to be used to measure the positional information to the second heads group after the step drive, before the movable body moves from the first area to the second area by being moved from the starting position in the first direction by the constant speed movement to form the pattern on a divided area subject to formation.

[0020] According to this method, the positional information of the movable body can be measured without switching the heads while the movable body performs a constant speed movement in the first direction to form a pattern on a divided area subject to formation on the object. Accordingly, it becomes possible to form a pattern on the object with good precision.

[0021] According to an eighth aspect of the present invention, there is provided a fourth exposure apparatus which sequentially exposes an energy beam on a plurality of divided areas placed in a shape of a matrix on an object, and forms a pattern on each of the plurality of divided areas, the apparatus comprising: a movable body which holds the object and moves along a predetermined plane; a position measurement system which has a plurality of heads provided on the movable body, and obtains positional information of the movable body based on measurement results of a predetermined number of heads of the plurality of heads which is obtained by irradiating a measurement beam on a measurement plane placed roughly parallel to the predetermined plane facing the movable body, receiving a return beam from the measurement plane, and measuring a position of the movable body in each measurement direction; and a control system which drives the movable body based on positional information obtained from the position measurement system, as well as switch at least one head of the predetermined number of heads used to compute the positional information of the body at the time besides when a constant speed movement of the movable body is performed in a first direction within the predetermined plane to form the pattern in the divided area subject to formation of the plurality of divided areas to another head.

[0022] According to this apparatus, while the movable body performs a constant speed movement in the first direction to form a pattern on a divided area subject to formation on the object, the head is not switched. Accordingly, it becomes possible to form a pattern on the object with good precision.

[0023] According to the ninth embodiment of the present invention, there is provided a fifth exposure method in which a plurality of divided areas placed in a shape of a matrix on an object is sequentially exposed by an energy beam, and a pattern is formed on each of the plurality of divided areas, the method comprising: obtaining a positional information of the movable body, based on measurement results of a predetermined number of heads of the plurality of heads provided on the movable body which moves along a predetermined plane holding the object, by irradiating a measurement beam on a measurement plane having an opening in part of the measurement plane which is placed facing the movable body and roughly parallel to the predetermined plane, receiving a return beam from the measurement plane, and measuring a position of the movable body in each measurement direction; switching at least one of the predetermined number of heads used to compute a positional information of the movable body according to a position of the movable body to a different head at a time besides when the movable body performs the constant speed movement in the first direction to form the pattern in the divided area subject to formation.

[0024] According to this method, while the movable body performs a constant speed movement in the first direction to form a pattern on a divided area subject to formation on the object, the head is not switched. Accordingly, it becomes possible to form a pattern on the object with good precision.

[0025] According to a tenth aspect of the present invention, there is provided a device manufacturing method, including forming a pattern on an object using any one of the first to fifth exposure methods of the present invention; and developing the object on which the pattern is formed.

Brief Description of Drawings

[0026]

FIG. 1 is a view schematically showing the configuration of an exposure apparatus related to an embodiment.

FIG. 2 is a view showing a configuration of an encoder system placed in the periphery of a projection optical system.

FIG. 3 is a view showing a configuration of an encoder system placed in the periphery of an alignment system.

FIG. 4 is an enlarged view of a wafer stage partially fractured.

FIG. 5 is a view showing a placement of encoder heads on the wafer stage.

FIG. 6 is a block diagram showing the main configuration of the control system related with the stage control in the exposure apparatus in FIG. 1.

FIG. 7 is a view (No. 1) showing a relation between a placement of encoder heads and a scale plate and a measurement area of the encoder system.

FIG. 8 is an enlarged view of wafer W1 in FIG. 7.

FIG. 9 is a view (No. 1) showing a movement track of an exposure center on a wafer in an exposure by a step-and-scan method.

FIG. 10(A) is a view (No. 1) showing an example of a switching procedure of encoder heads, FIG. 10(B) is a view showing a temporal change of the drive speed of the wafer stage before and after the switching, and FIGS. 10(C) and 10(D) are views (No. 2 and 3) showing an example of a switching procedure of encoder heads.

FIGS. 11(A) and 11(B) are views used to explain a linkage computing and a linkage process.

FIG. 12 is a view showing a rough configuration of a linkage process at the time when switching the encoder heads.

FIG. 13 is a view (No. 2) showing a relation between a placement of the encoder heads and the scale plate and the measurement area of the encoder system.

FIG. 14 is an enlarged view of wafer W2 in FIG. 13.

FIG. 15 is a view (No. 2) showing a movement track of the exposure center on a wafer in an exposure by a step-and-scan method.

FIGS. 16(A) to 16(C) are views (No. 4 to 6) showing an example of a switching procedure of encoder heads.

FIGS. 17(A) and 17(B) are views used to explain an occurrence principle of measurement errors in the encoder system involved with the acceleration of the wafer stage.

Description of Embodiments

[0027] An embodiment of the present invention will be described below, with reference to FIGS. 1 to 17(B).

[0028] FIG. 1 schematically shows the configuration of an exposure apparatus 100 related to the present embodiment. Exposure apparatus 100 is a projection exposure apparatus of the step-and-scan method, namely the so-called scanner. As it will be described later, a projection optical system PL is arranged in the embodiment, and in the description below, a direction parallel to an optical axis AX of projection optical system PL will be described as the Z-axis direction, a direction within a plane orthogonal to the Z-axis direction in which a reticle and a wafer are relatively scanned will be described as the Y-axis direction, a direction orthogonal to the Z-axis and the Y-axis will be described as the X-axis direction, and rotational (inclination) directions around the X-axis, the Y-axis, and the Z-axis will be described as θ x, θ y, and θ z directions, respectively.

[0029] Exposure apparatus 100 is equipped with an illumination system 10, a reticle stage RST holding reticle R, a projection unit PU, a wafer stage device 50 including wafer stages WST1 and WST2 on which a wafer W is mounted, a control system for these parts and the like.

[0030] Illumination system 10 includes a light source, an illuminance uniformity optical system, which includes an optical integrator and the like, and an illumination optical system that has a reticle blind and the like (none of which are shown), as is disclosed in, for example, U.S. Patent Application Publication No.2003/0025890 and the like. Illumination system 10 illuminates a slit-shaped illumination area IAR, which is set on reticle R with a reticle blind (a masking system), by an illumination light (exposure light) IL with a substantially uniform illuminance. Here, as one example, ArF excimer laser light (with a wavelength of 193 nm) is used as the illumination light IL.

[0031] On reticle stage RST, reticle R on which a circuit pattern or the like is formed on its pattern surface (the lower surface in Fig. 1) is fixed, for example, by vacuum chucking. Reticle stage RST is finely drivable within an XY plane, for example, by a reticle stage drive section 11 (not shown in FIG. 1, refer to FIG. 6) that includes a linear motor or the like, and reticle stage RST is also drivable in a scanning direction (in this case, the Y-axis direction, which is a direction orthogonal to the page surface in FIG. 1) at a predetermined scanning speed.

[0032] The positional information (including position information in the θz direction (θz rotation quantity)) of reticle stage RST in the XY plane (movement plane) is constantly detected, for example, at a resolution of around 0.25 nm by a reticle laser interferometer (hereinafter referred to as a "reticle interferometer") 16, which irradiates a measurement beam on a movable mirror 15 (the mirrors actually arranged are a Y movable mirror (or a retro reflector) that has a reflection surface which is orthogonal to the Y-axis direction and an X movable mirror that has a reflection surface orthogonal to the X-axis direction) shown in FIG. 1. Incidentally, to measure the positional information of reticle R at least in directions of three degrees of freedom, instead of, or together with reticle interferometer 16, the encoder system which is disclosed in, for example, U.S. Patent Application Publication No. 2007/0288121 and the like can be used.

[0033] Projection unit PU is placed below (-Z side) reticle stage RST in FIG. 1, and is held by a main frame (not shown) (metrology frame) which configures a part of a body. Projection unit PU has a barrel 40, and a projection optical system PL consisting of a plurality of optical elements held by barrel 40. As projection optical system PL, for example, a dioptric system is used, consisting of a plurality of lenses (lens elements) that has been disposed along optical axis AX, which is parallel to the Z-axis direction. Projection optical system PL is, for example, a both-side telecentric dioptric system that has a predetermined projection magnification (such as one-quarter, one-fifth, or one-eighth times). Therefore, when illumination light IL from illumination system 10 illuminates illumination area IAR, illumination light IL that has passed through reticle R which is placed so that its pattern surface substantially coincides with a first plane (an object plane) of projection optical system PL forms a reduced image of the circuit pattern (a reduced image of a part of the circuit pattern) of reticle R formed within illumination area IAR, via projection optical system PL, in an area (exposure area) IA conjugate to illumination area IAR on wafer W whose surface is coated with a resist (a sensitive agent) and is placed on a second plane (an image plane) side of projection optical system PL. And by reticle stage RST and wafer stages WST1 and WST2 being synchronously driven, reticle R is relatively moved in the scanning direction (the Y-axis direction) with respect to illumination area IAR (illumination light IL) while wafer W is relatively moved in the scanning direction (the Y-axis direction) with respect to exposure area IA (illumination light IL), thus scanning exposure of a shot area (divided area) on wafer W is performed, and the pattern of reticle R is transferred onto the shot area. That is, in the embodiment, the pattern of reticle R is generated on wafer W according to illumination system 10 and projection optical system PL, and then by the exposure of the sensitive layer (resist layer) on wafer W with illumination light IL, the pattern is formed on wafer W.

[0034] Incidentally, the main frame can be one of a gate type frame which is conventionally used, and a hanging support type frame disclosed in, for example, U.S. Patent Application Publication No. 2008/0068568 and the like.

[0035] In the periphery on the -Z side end of barrel 40, for example, a scale plate 21 is placed parallel to the XY plane, at a height substantially flush with a surface on the lower end of barrel 40. As shown in FIG. 2 in the embodiment, scale plate 21 is configured of four L-shaped sections (parts) 21_1, 21_2, 21_3, and 21_4, and the -Z end of barrel 40 is inserted, for example, inside a rectangular shaped opening 21a formed in the center. In this case, the width in the X-axis direction and the Y-axis direction of scale plate 21 is a and b, respectively, and the width of opening 21a in the X-axis direction and the Y-axis direction is a_i and b_i, respectively.

[0036] At a position away from scale plate 21 in the +X direction is a scale plate 22, which is placed substantially flush with scale plate 21, as shown in FIG. 1. Scale plate 22 is also configured, for example, of four L-shaped sections (parts) 22_1, 22_2, 22_3, and 22_4 as is shown in FIG. 3, and the -Z end of an alignment system ALG which will be described later is inserted, for example, inside a rectangular shaped opening 22a formed in the center. The width in the X-axis direction and the Y-axis direction of scale plate 22 is a and b, respectively, and the width of opening 22a in the X-axis direction and the Y-axis direction is a_i and b_i, respectively. Incidentally, in the embodiment, while the width of scale plates 21 and 22, and the width of openings 21a and 22a in the X-axis and the Y-axis directions were the same, the width does not necessarily have to be the same, and the width may differ in at least one of the X-axis and the Y-axis directions.

[0037] In the embodiment, scale plates 21 and 22 are supported by suspension from a main frame (not shown) (metrology frame) which supports projection unit PU and alignment system ALG. On the lower surface (a surface on the -Z side) of scale plates 21 and 22, a reflection type two-dimensional diffraction grating RG (refer to FIGS. 2, 3, and 4) is formed, consisting of a grating of a predetermined pitch, such as, for example, a grating of $1\mu m$ whose periodic direction is in a direction of 45 degrees with the X-axis serving as a reference (a direction of -45 degrees when the Y-axis serves as a reference), and a grating of a predetermined pitch, such as, for example, a grating of 1μm, whose periodic direction is in a direction of -45 degrees with the X-axis serving as a reference (-135 degrees when the Y-axis serves as a reference). However, due to the configuration of the two-dimensional grating RG and an encoder head which will be described later on, a non-effective area having a width t is included in each of the vicinity of the outer periphery of sections 21_1 to 21_4 and 22_1 to 22_4 configuring scale plates 21 and 22. The two-dimensional grating RG of scale plates 21 and 22 covers a movement range of wafer stages WST1 and WST2, respectively, at least at the time of exposure operation and alignment (measurement).

[0038] Wafer stage device 50, as shown in FIG. 1, is equipped with a stage base 12 supported almost horizontally by a plurality of (for example, three or four) vibration isolation mechanisms (omitted in the drawings) on the floor surface, wafer stages WST1 and WST2 placed on stage base 12, a wafer stage drive system 27 (only a part of the system shown in FIG. 1, refer to FIG. 6) which drives wafer stages WST1 and WST2, and a measurement system which measures the position of wafer stages WST1 and WST2 and the like. The measurement system is equipped with encoder systems 70 and 71, and a wafer laser interferometer system (hereinafter simply referred to as a wafer interferometer system) 18 and the like shown in FIG. 6. Incidentally, encoder systems 70 and 71, and wafer interferometer system 18 will be further described later in the description. However, in the embodiment, wafer interferometer system 18 does not necessarily have to be provided.

[0039] As shown in FIG. 1, stage base 12 is made of a member having a tabular form, and the degree of flatness of the upper surface is extremely high and serves as a guide surface when wafer stages WST1 and WST2 move. Inside stage base 12, a coil unit is housed, including a plurality of coils 14a placed in the shape of a matrix with the XY two-dimensional direction serving as a row direction and a column direction.

[0040] Incidentally, another base member to support the base by levitation can be provided separately from stage base 12, and stage base 12 can be made to function as a counter mass (reaction force canceller) which moves according to the law of conservation of momentum by the reaction force of the drive force of wafer stages WST1 and WST2.

[0041] As shown in FIG. 1, wafer stage WST1 has a stage main section 91, and a wafer table WTB1 which is placed above stage main section 91 and is supported in a non-contact manner with respect to stage main section 91 by a Z tilt drive mechanism (not shown). In this case, wafer table WTB1 is supported in a non-contact manner by Z tilt drive mechanism by adjusting the balance of the upward force (repulsion) such as the electromagnetic force and the downward force (gravitation) including the self-weight at three points, and is also finely driven at least in directions of three degrees of freedom, which are the Z-axis direction, the θx direction, and the θy direction. At the bottom of stage main section 91, a slider section 91a is arranged. Slider section 91a has a magnet unit made up of a plurality of magnets arranged two-dimensionally within the XY plane, a housing to house the magnetic unit, and a plurality of air bearings arranged in the periphery of the bottom surface of the housing. The magnet unit configures a planar motor 30 which uses the drive of an electromagnetic force (the Lorentz force) as disclosed in, for example, U.S. to which water repellent coat having sufficient resistance to exposure light IL (light in a vacuum ultraviolet region, in this case) is applied is formed on the surface of the first water repellent plate 28a, and a second water repellent area to which water repellent coat having resistance to exposure light IL inferior to the first water repellent area is applied is formed on the surface of the second water repellent plate 28b. In general, since it is difficult to apply water repellent coat having sufficient resistance to exposure light IL (light in a vacuum ultraviolet region, in this case) to a glass plate, it is effective to separate the water repellent plate into two sections in this manner, i.e. the first water repellent plate 28a and the second water repellent plate 28b around it. Incidentally, the present invention is not limited to this, and two types of water repellent coat that have different resistance to exposure light IL may also be applied on the upper surface of the same plate in order to form the first water repellent area and the second water repellent area. Further, the same kind of water repellent coat may be applied to the first and second water repellent areas. For example, only one water repellent area may also be formed on the same plate.

[0042] Further, as is obvious from FIG. 2(A), at the end portion on the +Y side of the first water repellent plate 28a, a rectangular cutout is formed in the center portion in the X-axis direction, and a measurement plate 30 is embedded inside the rectangular space (inside the cutout) that is enclosed by the cutout and the second water repellent plate 28b. A fiducial mark FM is formed in the center in the longitudinal be configured by a rough/fine movement stage.

[0043] On wafer table WTB1, wafer W is mounted via a wafer holder (not shown), and is fixed by a chuck mechanism (not shown), such as, for example, vacuum suction (or electrostatic adsorption). Although it is not shown, on one of the diagonal lines on wafer table WTB1, a first fiducial mark plate and a second fiducial mark plate are provided, with the wafer holder in between. On the upper surface of the first and second fiducial mark plates, a plurality of reference marks which are detected by a pair of reticle alignment systems 13A and 13B and alignment system ALG are formed, respectively. Incidentally, the positional relation between the plurality of reference marks on the first and second fiducial plates are to be known.

[0044] Wafer stage WST2 is also configured in a similar manner as wafer stage WST1.

[0045] Encoder systems 70 and 71 obtain (measure) positional information of wafer stages WST1 and WST2, respectively, in directions of six degrees of freedom (X, Y, Z, θ x, θ y, θ z) in an exposure time movement area (in an area where the wafer stage moves when exposing a plurality of shot areas on wafer W) including an area right below projection optical system PL, and in an alignment time movement area including an area right below alignment system ALG. Now, a configuration and the like of encoder systems 70 and 71 will be described in detail. Incidentally, exposure time movement area (a first movement area) is an area in which the wafer stage moves during an exposure operation within the exposure station (a first area) where the exposure of the wafer is performed via projection optical system PL, and the exposure operation, for example, includes not only exposure of all of the shot areas on the wafer to which the pattern should be transferred, but also the preparatory operations (for example, detection of the fiducial marks previously described) for exposure. Measurement time movement area (a second movement area) is an area in which the wafer stage moves during a measurement operation within the measurement station (a second area) where the measurement of the positional information is performed by detection of alignment marks on the wafer by alignment system ALG, and the measurement operation, for example, includes not only detection of a plurality of alignment marks on the wafer, but also detection (furthermore, measurement of positional information (step information) of the wafer in the Z-axis direction) of fiducial marks by alignment system ALG.

[0046] In wafer tables WTB1 and WTB2, as shown in an planar view in FIGS. 2 and 3, respectively, encoder heads (hereinafter appropriately referred to as a head) 60_1 to 60_4 are placed in each of the four corners on the upper surface. In this case, the separation distance in the X-axis direction between heads 60_1 and 60_2 and the separation distance in the X-axis direction between heads 60_3 and 60_4 are both equal to A. Further, the separation distance in the Y-axis direction between heads 60_1 and 60_4 and the separation distance in the Y-axis direction between heads 60_2 and 60_3 are both equal to B. These separation distances A and B are larger than width a_i and b_i of opening 21a of scale plate 21. Specifically, taking into consideration width t of the non-effective area previously described, $A \geq a_i+2t$, $B \geq b_i+2t$. Heads 60_1 to 60_4 are housed, respectively, inside holes of a predetermined depth in the Z-axis direction which have been formed in wafer tables WTB1 and WTB2 as shown in FIG. 4, with head 60_1 taken up as a representative.

[0047] As shown in FIG. 5, head 60_1 is a two-dimensional head in a -135 degrees direction with the X-axis serving as a reference (in other words, a -45 degrees direction with the X-axis serving as a reference) and whose measurement direction is in the Z-axis direction. Similarly, heads 60_2 to 60_4 are two-dimensional heads that are in a 225 degrees direction with the X-axis serving as a reference (in other words, a 45 degrees direction with the X-axis serving as a reference) whose measurement direction is in the Z-axis direction, a 315 degrees direction with the X-axis serving as a reference (in other words, a -45 degrees direction with the X-axis serving as a reference) whose measurement direction is in the Z-axis direction, and a 45 degrees direction with the X-axis serving as a reference whose measurement direction is in the Z-axis direction, respectively. As is obvious from FIGS. 2 and 4, heads 60_1 to 60_4 irradiate a measurement beam on the two dimensional diffraction grating RG formed on the surface of sections 21_1 to 21_4 of scale plate 21 or sections 22_1 to 22_4 of scale plate 22 that face the heads, respectively, and by receiving the reflected / diffraction beams from the two-dimensional grating, measure the position of wafer table WTB1 and WTB2 (wafer stages WST1 and WST2) for each of the measurement directions. Now, as each of the heads 60_1 to 60_4, a sensor head having a configuration similar to a sensor head for measuring variation as is disclosed in, for example, U.S. Patent No. 7,561,280, can be used.

[0048] In heads 60_1 to 60_4 configured in the manner described above, since the optical path lengths of the measurement beams in air are extremely short, the influence of air fluctuation can mostly be ignored. However, in the embodiment, the light source and a photodetector are arranged external to each head, or more specifically, inside (or outside) stage main section 91, and only the optical system is arranged inside of each head. And the light source, the photodetector, and the optical system are optically connected via an optical fiber (not shown). In order to improve the positioning precision of wafer table WTB (fine movement stage), air transmission of a laser beam and the like can be performed between stage main section 91 (rough movement stage) and wafer table WTB (fine movement stage) (hereinafter shortly referred to as a rough/fine movement stage), or a configuration can be employed where a head is provided in stage main section 91 (rough movement stage) so as to measure a position of stage main section 91 (rough movement stage) using the head and to measure relative displacement of the rough/fine movement stage with another sensor.

[0049] When wafer stage WST1 and WST2 are located within the exposure time movement area previously described, head 60_1 configures two-dimensional encoders 70_1 and 71_1 (refer to FIG. 6) which irradiate a measurement beam (measurement light) on (section 21_1 of) scale plate 21, receive the diffraction beam from the grating whose periodical direction is in a 135 degrees direction, or in other words, whose periodical direction is in a -45 degrees (hereinafter simply referred to as a -45 degrees direction), with the X-axis serving as a reference formed on the surface (lower surface) of scale plate 21, and measure the position of wafer tables WTB1 and WTB2 in the -45 degrees direction and in the Z-axis direction. Similarly, heads 60_2 to 60_4 each configure two-dimensional encoders 70_2 to 70_4 and 71_2 to 71_4 (refer to FIG. 6) which irradiate a measurement beam (measurement light) on (sections 21_2 to 21_4 of) scale plate 21, respectively, receive a diffraction beam from the grating whose periodical direction is in a 225 degrees direction, or in other words, whose periodical direction is in a +45 degrees (hereinafter simply referred to as a 45 degrees direction) with the X-axis serving as a reference, a 315 degrees direction, or in other words, whose periodical direction is in a -45 degrees direction with the X-axis serving as a reference, and a 45 degrees direction, formed on the surface (lower surface) of scale plate 21, and measure the position in the 225 degrees (45 degrees) direction and in the Z-axis direction, the position in the 315 degrees (-45 degrees) direction and the Z-axis direction, and the position in the 45 degrees direction and the Z-axis direction of wafer tables WTB1 and WTB2.

[0050] Further, when wafer stage WST1 and WST2 are located within the measurement time movement area previously described, head 60_1 configures two-dimensional encoders 70_1 and 71_1 (refer to FIG. 6) which irradiate a measurement beam (measurement light) on (section 22_1 of) scale plate 22, receive the diffraction beam from the grating whose periodical direction is in a 135 degrees direction (-45 degrees direction) FIG. 7), which is similar to the one disclosed in, U.S. Patent Application Publication No. 2002/0041377 description referred to previously, and the like.

[0051] On a surface on the -Y side of measurement table MTB, a fiducial bar (hereinafter, shortly referred to as an "FD bar") 46, which is made up of a bar-shaped member having a rectangular sectional shape and serves as a reference member, is attached extending in the X-axis direction, as shown in FIG. 2(B). FD bar 46 is kinematically supported on measurement stage MST by a full-kinematic mount structure.

[0052] Since FD bar 46 serves as a prototype standard (measurement standard), optical glass ceramics with a low coefficient of thermal expansion, such as Zerodur (the brand name) of Schott AG are employed as the materials. The flatness degree of the upper surface (the surface) of FD bar 46 is set high to be around the same level as a so-called datum plane plate. Further, a reference grating (for example, a diffraction grating) 52 whose periodic direction is the Y-axis direction is respectively formed in the vicinity of the end portions on one side and the other side in the longitudinal direction of FD bar 46. The pair of reference gratings 52 is formed placed apart from each other at a predetermined distance symmetric to the center in the X-axis direction of FD bar 46, or more specifically, formed in a symmetric placement to centerline CL.

[0053] Further, on the upper surface of FD bar 46, a plurality of reference marks M is formed. The plurality of reference marks M are formed in three-row arrays in the Y-axis direction in the same pitch, and the array of each row is formed being encoders (hereinafter shortly referred to as an encoder as appropriate) 70_1 to 70_4, and 71_1 to 71_4 are supplied to main controller 20 (refer to FIG. 6). Main controller 20 obtains the positional information of wafer table WTB1 and WTB2 within the exposure time movement area including the area right under projection optical system PL, based on the measurement values of at least three encoders (in other words, at least three encoders that output effective measurement values) which face the lower surface of (sections 21_1 to 21_4 configuring) scale plate 21 on which the two-dimensional diffraction grating RG is formed. Similarly, main controller 20 obtains the positional information of wafer table WTB1 and WTB2 within the measurement time movement area including the area right under alignment system ALG, based on the measurement values of at least three encoders (in other words, at least three encoders that output effective measurement values) which face the lower surface of (sections 22_1 to 22_4 configuring) scale plate 22 on which the two-dimensional diffraction grating RG is formed.

[0054] Further, in exposure apparatus 100 of the embodiment, the position of wafer stages WST1 and WST2 (wafer tables WTB1 and WTB2) can be measured with wafer interferometer system 18 (refer to FIG. 6), independently from encoder systems 70 and 71. Measurement results of wafer interferometer system 18 are used secondarily such as when correcting (calibrating) a long-term fluctuation (for example, temporal deformation of the scale) of the measurement results of encoder systems 70 and 71, or as backup at the time of output abnormality in encoder systems 70 and 71. Incidentally, details on wafer interferometer system 18 will be omitted.

[0055] Alignment system ALG is an alignment system of an off-axis method placed on the +X side of projection optical system PL away by a predetermined distance, as shown in FIG. 1. In the embodiment, as alignment system ALG, as an example, an FIA (Field Image Alignment) system is used which is a type of an alignment sensor by an image processing method that measures a mark position by illuminating a mark using a broadband (a wide band wavelength range) light such as a halogen lamp and performing image processing of the mark image. The imaging signals from alignment system ALG are supplied to main controller 20 (refer to FIG. 6), via an alignment signal processing system (not shown).

[0056] Incidentally, alignment system ALG is not limited to the FIA system, and an alignment sensor, which irradiates a coherent detection light to a mark and detects a scattered light or a diffracted light generated from the mark or makes two diffracted lights (for example, diffracted lights of the same order or diffracted lights being diffracted in the same direction) generated from the mark interfere and detects an interference light, can naturally be used alone or in combination as needed. As alignment system ALG, an alignment system having a plurality of detection areas like the one disclosed in, for example, U.S. Patent Application Publication No. 2008/0088843 can be employed.

[0057] Moreover, in exposure apparatus 100 of the embodiment, a multiple point focal point position detection system (hereinafter shortly referred to as a multipoint AF system) AF (not shown in FIG. 1, refer to FIG. 6) by the oblique incidence method having a similar configuration as the one disclosed in, for example, U.S. Patent No. 5,448,332 and the like, is arranged at the measurement station together with alignment system ALG. At least a part of a measurement operation by the multipoint AF system AF is performed in parallel with the mark detection operation by alignment system ALG, and the positional information of the wafer table is also measured during the measurement operation by the encoder system previously described. Detection signals of multipoint AF system AF are supplied to main controller 20 (refer to FIG. 6) via an AF signal processing system (not shown). Main controller 20 detects positional information (step information/

unevenness information) of the wafer W surface in the Z-axis direction based on the detection signals of multipoint AF system AF and the measurement information of the encoder system previously described, and in the exposure operation, performs a so-called focus leveling control of wafer W during the scanning exposure based on prior detection results and the measurement information (positional information in the Z-axis, the θx and θy directions) of the encoder system previously described. Incidentally, multipoint AF system can be arranged within the exposure station in the vicinity of projection unit PU, and at the time of exposure operation, the so-called focus leveling control of wafer W can be performed by driving the wafer table while measuring the surface position information (unevenness information) of the wafer surface.

[0058] In exposure apparatus 100, furthermore, above reticle R, a pair of reticle alignment detection systems 13A and 13B (not shown in FIG. 1, refer to FIG. 6) of a TTR (Through The Reticle) method which uses light of the exposure wavelength, as is disclosed in, for example, U.S. Patent No. 5,646,413 and the like, is arranged. Detection signals of reticle alignment systems 13A and 13B are supplied to main controller 20 via an alignment signal processing system (not shown). Incidentally, reticle alignment can be performed using an aerial image measuring instrument (not shown) provided on wafer stage WST, instead of the reticle alignment system.

[0059] FIG. 6 is a block diagram showing a partially omitted control system related to stage control in exposure apparatus 100. This control system is mainly configured of main controller 20. Main controller 20 includes a so-called microcomputer (or workstation) consisting of a CPU (Central Processing Unit), ROM (Read Only Memory), RAM (Random Access Memory) and the like, and has overall control over the entire apparatus.

[0060] In exposure apparatus 100 configured in the manner described above, when manufacturing a device, main controller 20 moves one of wafer stages WST1 and WST2 on which the wafer is loaded within the measurement station (measurement time movement area), and the measurement operation of the wafer by alignment system ALG and multipoint AF system is performed. More specifically, in the measurement time movement area on the wafer held by one of wafer stages WST1 and WST2, mark detection using alignment system ALG, or the so-called wafer alignment (such as Enhanced Global Alignment (EGA) disclosed in, for example, U.S. Patent No. 4,780,617 and the like) and measurement of the surface position (step/ unevenness information) of the wafer using the multipoint AF system are performed. On such alignment, encoder system 70 (encoders 70_1 to 70_4) or encoder system 71 (encoders 71_1 to 71_4) obtains (measures) the positional information of wafer stages WST1 and WST2 in directions of six degrees of freedom (X, Y, Z, θx, θy, and θz).

[0061] After the measurement operation such as the wafer alignment and the like, one of the wafer stages (WST1 or WST2) is moved to exposure time movement area, and main controller 20 performs reticle alignment and the like in a procedure (a procedure disclosed in, for example, U.S. Patent No. 5,646,413 and the like) similar to a normal scanning stepper, using reticle alignment systems 13A and 13B, fiducial mark plates (not shown) on the wafer table (WTB1 or WTB2) and the like.

[0062] Then, main controller 20 performs an exposure operation by the step-and-scan method, based on the measurement results of the wafer alignment and the like, and a pattern of reticle R is transferred onto each of a plurality of shot areas on wafer W. The exposure operation by the step-and-scan method is performed by alternately repeating a scanning exposure operation where synchronous movement of reticle stage RST and wafer stage WST1 or WST2 is performed, and a movement (stepping) operation between shots where wafer stage WST1 or WST2 is moved to an acceleration starting position for exposure of the shot area. At the time of the exposure operation, encoder system 70 (encoders 70_1 to 70_4) or encoder system 71 (encoders 71_1 to 71_4) obtains (measures) the positional information of one of the wafer stages WST1 or WST2, in directions of six degrees of freedom (X, Y, Z, θx, θy, and θz).

[0063] Further, exposure apparatus 100 of the embodiment is equipped with two wafer stages WST1 and WST2. Therefore, in parallel with performing an exposure by the step-and-scan method with respect to the wafer loaded on one of the wafer stages, such as, for example, wafer stage WST1, a parallel processing operation is performed in which wafer alignment and the like is performed on the wafer mounted on the other stage WST2.

[0064] In exposure apparatus 100 of the embodiment, as is previously described, main controller 20 obtains (measures) the positional information of wafer stage WST1 in directions of six degrees of freedom (X, Y, Z, θx, θy, and θz) using encoder system 70 (refer to FIG. 6), within both the exposure time movement area and the measurement time movement area. Further, main controller 20 obtains (measures) the positional information of wafer stage WST2 in directions of six degrees of freedom (X, Y, Z, θx, θy, and θz) using encoder system 71 (refer to FIG. 6), within both the exposure time movement area and the measurement time movement area.

[0065] Now, the principles of position measurement in directions of three degrees of freedom (also shortly referred to as the X-axis direction, the Y axis direction and the θz direction (X, Y, θ z)) within the XY plane by encoder systems 70 and 71 are further described. Here, measurement results or measurement values of encoder heads 60_1 to 60_4 or encoders 70_1 to 70_4 refer to measurement results of encoder heads 60_1 to 60_4 or encoders 70_1 to 70_4 in the measurement direction which is not in the Z-axis direction.

the position to place the reference surface at is not limited to projection unit PU, and the fixed mirror does not always have to be used to measure the positional information of wafer stage WST.

[0066] Further, in the embodiment, positional information of wafer stage WST measured by interferometer system

118 is not used in the exposure operation and the alignment operation which will be described later on, and was mainly to be used in calibration operations (more specifically, calibration of measurement values) of the encoder system, however, the measurement information (more specifically, at least one of the positional information in directions of five degrees of freedom) of interferometer system 118 can be used in the exposure operation and/or the alignment operation. In the embodiment, the encoder system measures positional information of wafer stage WST in directions of three degrees of freedom, or more specifically, the X-axis, the Y-axis, and the θz directions. Therefore, in the exposure operation and the like, of the measurement information of interferometer system 118, positional information related to a direction that is different from the measurement direction (the X-axis, the Y-axis, and the θz direction) of wafer stage WST by the encoder system, such as, for example, positional information related only to the θx direction and/or the θy direction can be used, or in addition to the positional information in the different direction, positional information related to the same direction (more specifically, at least one of the X-axis, the Y-axis, and the θz directions) as the measurement direction of the encoder system can also be used. Further,

[0067] Similarly, when wafer stage WST1 is located in the exposure time movement area, and also within a second area A_2, which is an area (an area (except for area A_0) within the second quadrant whose origin is exposure center P) on the -X side and also on the +Y side with respect to exposure center P, heads 60_1, 60_2, and 60_3 face sections 21_1, 21_2, and 21_3 of scale plate 21, respectively. When wafer stage WST1 is located in the exposure time movement area, and also within a third area A_3, which is an area (an area (except for area A_0) within the third quadrant whose origin is exposure center P) on the -X side and also on the -Y side with respect to exposure center P, heads 60_2 60_3, and 60_4 face sections 21_2, 21_3, and 21_4 of scale plate 21, respectively. When wafer stage WST1 is located in the exposure time movement area, and also within a fourth area A_4, which is an area (an area (except for area A_0) within the fourth quadrant whose origin is exposure center P) on the +X side and also on the -Y side with respect to exposure center P, heads 60_3, 60_4, and 60_1 face sections 21_3, 21_4, and 21_1 of scale plate 21, respectively.

[0068] In the embodiment, as well as a condition ($A \geq a_i+2t$, $B \geq b_i+2t$) for the configuration and placement of encoder heads 60_1 to 60_4 and scale plate 21 previously described, condition $A \geq a_i+W+2t$, $B \geq b_i+L+2t$ is added, taking into consideration the size (W, L) of the shot area on the wafer in which the pattern is formed. In this case, W and L are the width of the shot area in the X-axis direction and the Y axis direction, respectively. W and L are equal to the distance of the scanning exposure section and the distance of stepping in the X-axis direction, respectively. Under this condition, as shown in FIGS. 7 and 13, in the case wafer stage WST1 is positioned within a cross-shaped area A_0 (an area whose longitudinal direction is in the Y-axis direction and has a width $A-a_i-2t$ and an area an area whose longitudinal direction is in the X-axis direction and has a width $B-b_i-2t$ that pass through exposure center P (hereinafter referred to as a zeroth area)) in which exposure position P serves as the center, all of the heads 60_1 to 60_4 on wafer stage WST1 face scale plate 21 (sections 21_1 to 21_4 corresponding to the heads). Accordingly, within the zeroth area A_0, effective measurement values from all of the heads 60_1 to 60_4 (encoders 70_1 to 70_4) are sent to main controller 20. Incidentally, in the embodiment, in addition to the conditions ($A \geq a_i+2t$, $B \geq b_i+2t$) described above, condition $A \geq a_i +W+2t$, $B \geq b_i +L+2t$ may be added taking into consideration the size (W, L) of the shot area on the wafer in which the pattern is formed. In this case, W and L are the width of the shot area in the X-axis direction and the Y axis direction, respectively. W and L are equal to the distance of the scanning exposure section and the distance of stepping in the X-axis direction, respectively.

[0069] Main controller 20 computes the position (X, Y, θ z) of wafer stage WST1 in the XY plane, based on measurement results of heads 60_1 to 60_4 (encoders 70_1 to 70_4). In this case, measurement values (each described as C_1 to C_4) of encoders 70_1 to 70_4 depend upon the position (X, Y, θz) of wafer stage WST1 as in formulas (1) to (4) below.

$$C_1 = -(\cos\theta z + \sin\theta z)X/\sqrt{2} + (\cos\theta z - \sin\theta z)Y/\sqrt{2} + \sqrt{2}p\sin\theta z \quad \ldots (1)$$

$$C_2 = -(\cos\theta z - \sin\theta z)X/\sqrt{2} - (\cos\theta z + \sin\theta z)Y/\sqrt{2} + \sqrt{2}p\sin\theta z \quad \ldots (2)$$

$$C_3 = (\cos\theta z + \sin\theta z)X/\sqrt{2} - (\cos\theta z - \sin\theta z)Y/\sqrt{2} + \sqrt{2}p\sin\theta z \quad \ldots (3)$$

$$C_4 = (\cos\theta z - \sin\theta z)\,X/\sqrt{2} + (\cos\theta z + \sin\theta z)\,Y/\sqrt{2} + \sqrt{2}p\sin\theta z \ \ldots \ (4)$$

[0070] However, as shown in FIG. 5, p is the distance of the head in the X-axis and the Y-axis directions from the center of wafer table WTB1 (WTB2).

[0071] Main controller 20 specifies three heads (encoders) facing scale plate 21 according to areas A_0 to A_4 where wafer stage WST1 is positioned and forms a simultaneous equation by choosing from the formulas (1) to (4) above the formula which the measurement values of the three heads follow, and by solving the simultaneous equation using the measurement values of the three heads (encoders), computes the position (X, Y, θz) of wafer sage WST1 in the XY plane. For example, when wafer stage WST1 is located in the first area A_1, main controller 20 forms a simultaneous equation from formulas (1), (2) and (4) that measurement values of heads 60_1, 60_2, and 60_4 (encoders 70_1, 70_2, and 70_4) follow, and solves the simultaneous equation by substituting the measurement values of each of the heads into the left side of formulas (1), (2) and (4), respectively.

[0072] Incidentally, in the case wafer stage WST1 is located in the zeroth area A_0, main controller 20 can randomly select three heads from heads 60_1 to 60_4 (encoders 70_1 to 70_4). For example, after the first wafer stage WST1 has moved from the first area to the zeroth area, heads 60_1, 60_2, and 60_4 (encoders 70_1, 70_2, and 70_4) corresponding to the first area are preferably selected.

[0073] Main controller 20 drives (position control) wafer stage WST1 within the exposure time movement area, based on the computation results (X, Y, θz) above.

[0074] In the case wafer stage WST1 is located within measurement time movement area, main controller 20 measures the positional information in directions of three degrees of freedom (X, Y, θz), using encoder system 70. The measurement principle and the like, here, is the same as in the case when wafer stage WST1 is located within the measurement time movement area, except for the point where exposure center P is replaced with the detection center of alignment system ALG, and (sections 21_1 to 21_4 of) scale plate 21 is replaced with (sections 22_1 to 22_4 of) scale plate 22.

[0075] Furthermore, main controller 20 switches and uses three heads that includes at least one different head, out of heads 60_1 to 60_4 that face scale plates 21 and 22, according to the position of wafer stages WST1 and WST2. In this case, when switching the encoder head, a linkage process to secure the continuity of the position measurement results of the wafer stage is performed, as is disclosed in, for example, U.S. Patent Application Publication No. 2008/0094592 and the like.

[0076] Now, switching and linkage process of heads 60_1 to 60_4 at the time of exposure operation by the step-and-scan method will be further described.

[0077] As a first example, an exposure operation with respect to wafer W_1 shown in FIG. 7 will be described. In this case, on wafer W_1, as an example, a total of 36 shot areas S_1 to S_{36}, which are arranged in an even number in the X-axis direction and an odd number in the Y-axis direction, are to be arranged, as is shown enlarged in FIG. 8.

[0078] An exposure by the step-and-scan method is performed with respect to wafer W_1, along a path shown in FIG. 9. Incidentally, the path in FIG. 9 shows the track of exposure center (the center of exposure area IA) P which passes over each of the shot areas. The solid line portion of this track shows a movement track of exposure center P on scanning exposure of each of the shots, and the dotted line portion (broken line portion) shows a step movement track of exposure center P between adjacent shot areas in the scanning direction and in a direction besides the scanning direction. Incidentally, although in actual, exposure center P is fixed and the wafer moves in a direction opposite to the path shown in FIG. 9, for the sake of convenience, the exposure center is to move with respect to a fixed wafer in the description.

[0079] In exposure apparatus 100 of the embodiment, three heads of heads 60_1 to 60_4 opposing scale plate 21 are switched and used, in response to the position of wafer stage WST1. Accordingly, when wafer stage WST1 moves from one of the areas A_1 to A_4 shown in FIG. 7 to another area via. area A_0, the head which is to be used is switched. Therefore, in FIG. 9, overlaying the track of exposure center P on wafer W_1, areas B_0 to B_4 are shown which correspond to the set of heads opposing scale plate 21 when wafer stage WST1 is located at the position in the track of exposure center P.

[0080] Areas B_0 to B_4 in FIG. 9 correspond to movement areas A_0 to A_4 of wafer stage WST1 in FIG. 7, respectively. For example, when performing scanning exposure of the shot areas within area B_i, or when performing a step movement to the next shot area, wafer stage WST1 moves within area A_i. Accordingly, when exposure center P is located in area B_1, heads 60_4, 60_1, and 60_2 face scale plate 21. Similarly, when exposure center P is located in areas B_2, B_3, B_4, and B_0, heads 60_1, 60_2, and 60_3, heads 60_2, 60_3, and 60_4, heads 60_3, 60_4, and 60_1, and all of the heads 60_1 to 60_4 face scale plate 21, respectively.

[0081] Accordingly, exposure center P moves over the track shown in FIG. 9 by the scanning exposure of the shot area or the step movement between shot areas, and the head which is to be used is switched when exposure center P moves from one of the areas B_1 to B_4 to another area via area B_0. Therefore, in FIG. 9, occurrence places of the switching of the heads with respect to wafer W are shown by a double circle.

[0082] For example, first of all, after exposure center P performs exposure processing on the first shot area S_1 to the third shot area S_3 and has moved from area B_1 to area B_0, switching of the head (a first switching) occurs when exposure processing of the fourth shot area S_4 within area B_0 shown inside circle C_1 is performed and exposure center P is stepped to the fifth shot area S_5 within area B_2. Now, as is previously described, when exposure center P is located in areas B_1, B_0, and B_2, heads 60_0, 60_1, and 60_2, all of the heads 60_1 to 60_4, heads 60_1, 60_2, and 60_3 face scale plate 21, respectively. Accordingly, in the first switching, the heads to be used are switched from heads 60_4, 60_1, and 60_2 to heads 60_1, 60_2, and 60_3.

[0083] FIG. 10 (A) shows an enlarged view of the inside of circle C_1 in FIG. 9 used to explain the details of the first switching, and FIG. 10(B) shows a temporal change of velocity Vy in the Y-axis direction of wafer stage WST1 after the first switching.

[0084] After the exposure processing of the third shot area S_3 has been performed, main controller 20 drives (position control) wafer stage WST1 based on measurement results of heads 60_4, 60_1, and 60_2 (encoders 70_4, 70_1, and 70_2), so that exposure center P is moved to an acceleration starting position e_4 to expose the fourth shot area S_4. When exposure center P reaches acceleration starting position e_4, main controller 20 starts a synchronous movement of wafer stage WST1 (wafer W_1) and reticle stage RST (reticle R). In other words, main controller 20 accelerates and drives wafer stage WST1, and concurrently drives reticle stage RST which follows the movement of wafer stage WST1, in a direction opposite to wafer stage WST1 also at a velocity which is a multiple of the inverse number of projection magnification β of the velocity of wafer stage WST1. As shown in FIG. 10 (B), the velocity of both stages WST1 and WST2 becomes constant, after an acceleration time T_a has passed from the beginning of acceleration (time t_4).

[0085] After the acceleration has been completed, for a settling time T_b until the beginning of exposure, main controller 20 drives reticle stage RST so that reticle stage RST follows wafer stage WST1 until a displacement error between wafer W_1 and reticle R becomes a predetermined relation (approximately zero).

[0086] After settling time T_b, main controller 20 drives wafer stage WST1 in a constant manner, based on measurement results of heads 60_4, 60_1, and 60_2 (encoders 70_4, 70_1, and 70_2). This allows exposure area IA (exposure center P) to move at a constant velocity from the -Y edge to the +Y edge of shot area S4 as is shown in FIG. 10(A) during exposure time T_c, and scanning exposure of shot area S_4 is performed. During the scanning exposure, the synchronous movement state at a constant velocity of wafer W_1 and reticle R is maintained.

[0087] After the exposure has been completed, wafer stage WST1 moves in a constant velocity during a uniform velocity overscan time (postsettling time) T_d. During this movement, as is shown in FIG. 10(A), exposure center P passes through the first switching position P_1 on the +Y side of shot area S_4 at a constant velocity. At this point, main controller 20 switches the heads to be used from heads 60_4, 60_1, and 60_2 (encoders 70_4, 70_1, and 70_2) to heads 60_1, 60_2, and 60_3 (encoders 70_1, 70_2, and 70_3). Now, main controller 20 performs a linkage process in order to secure the continuity of measurement results of the position of wafer stage WST1 before and after the switching. In other words, main controller 20 resets measurement values C_3 of head 60_3 which is to be newly used after the switching, so that measurement results (X', Y', θz') of the position of wafer stage WST1 obtained from measurement values of heads 60_1, 60_2, and 60_3 coincide with measurement results (X, Y, θz) of wafer stage WST1 obtained from measurement values of heads 60_4, 60_1, and 60_2. Details of this linkage process will be describer further in the description.

[0088] After the switching, main controller 20, decelerates and drives wafer stage WST1, based on the measurement results of heads 60_1, 60_2, and 60_3 (encoders 70_1, 70_2, and 70_3) during a deceleration overscan time T_e. At the same time, reticle stage RST is also decelerated. Incidentally, in the deceleration overscan time T_e, wafer stage WST1 is moved in the X-axis direction as well, in parallel with being moved in the Y-axis direction. This makes exposure center P draw a U-shaped track from the +Y edge of shot area S_4 and perform a step movement toward the next shot area within area B_2.

[0089] After the deceleration of wafer stage WST1 has been completed, main controller 20 continues to drive wafer stage WST1 and reticle stage RST as is previously described, however, in opposite directions, and exposes the next shot area S_5.

[0090] The measurement results of encoder system 70 (71) include a measurement error caused by a production error of the scale and the like.

[0091] Now, in the following description, the four heads will be abstractly described as Enc1, Enc2, Enc3, and Enc4 so as to describe the principle of the switching of the heads and the linkage process.

[0092] FIG. 11(A) shows the (track of) a temporal change of a position coordinate (X, Y, θz) of wafer stage WST1 computed from the measurement values of encoders Enc1, Enc2, and Enc3, and a position coordinate (X', Y', θz') of wafer stage WST1 computed from the measurement values of encoders Enc2, Enc3, and Enc4, before and after the switching of heads from Enc1, Enc2, and Enc3 to Enc2, Enc3, and Enc4. The track of the measurement results of the position of wafer stage WST1 fluctuates minutely by measurement errors due to the production error of the scale and the like. Therefore, in a simple linkage process like the one disclosed in U.S. Patent Application Publication No. 2008/0094592 and the like, measurement values of encoder Enc4 (in this case, measurement value C_4 of head 60_4)

which is to be newly used will be reset taking in the measurement errors as well. In the embodiment, a linkage process which prevents such a situation from occurring is employed.

[0093] Next, a principle of a linkage process performed in exposure apparatus 100 of the embodiment will be described. In the embodiment, main controller 20 controls the position coordinates of wafer stage WST1 by an interval of, for example, 96 μ sec. At each control sampling interval, a position servo control system (part of main controller 20) updates the current position of wafer stage WST1, computes thrust command values and the like to position the stage to a target position, and outputs the results to wafer stage drive system 27. As is previously described, the current position of wafer stage WST1 is computed using three measurement values of heads 60_1 to 60_4 (encoders 70_1 to 70_4) which configure encoder system 70. The measurement values of these heads (encoders) are monitored at a time interval (measurement sampling interval) much shorter than the control sampling interval.

[0094] FIG. 12 shows an outline of a drive (position control) of wafer stage WST, switching of heads 60_1 to 60_4 (encoders 70_1 to 70_4), and a linkage process which comes with the switching, based on the measurement results of encoder system 70. Reference code CSCK in FIG. 12 indicates the generation timing of a sampling clock (a control clock) of the position control of wafer stage WST1, and reference code MSCK indicates a generation timing of a sampling clock (a measurement clock) of the measurement of the encoder.

[0095] Main controller 20 monitors the measurement values of (the four encoders Enc1, Enc2, Enc3, and Enc4 which configure) encoder system 70 for each control clock (CSCK).

[0096] At the time of the first switching, encoders Enc1, Enc2, Enc3, and Enc4 correspond to heads 60_4, 60_1, 60_2, and 60_3 (encoders 70_4, 70_1, 70_2, and 70_3), respectively.

[0097] At the time of the control clock, main controller 20 computes a position coordinate (X, Y, θz) of wafer stage WST1 using a simultaneous equation consisting of formulas (1) to (3) which correspond to the measurement values of encoders Enc1, Enc2, and Enc3 like the time of the first control clock, as well as compute a position coordinate (X' , Y', θz') of wafer stage WST1 using the measurement values of encoders Enc2, Enc3, and Enc4 which are to be used after the switching.

[0098] Main controller 20 outputs a stage position coordinate (X, Y, θz) computed from the measurement values of encoders Enc1, Enc2, and Enc3 to wafer stage drive system 27 as a stage coordinate system for servo control and drives wafer stage WST1, until the scanning exposure (exposure time Tc) of shot area S_4 has been completed. After the exposure has been completed, main controller 20 switches from encoders Enc1, Enc2, and Enc3 to encoders Enc2, Enc3, and Enc4, at the time of the third control clock during uniform velocity overscan time (postsettling time) Td.

[0099] As shown in FIG. 11(A), the continuity of the stage position coordinate is not satisfied in the simple linkage process, due to the measurement errors caused by the production error of the scale and the like. Therefore, in parallel with the scanning exposure to shot area S_4, or in other words, driving wafer stage WST1 in a constant manner for a part Q1 of the scanning exposure section shown in FIG. 10(A), main controller 20 performs a preprocessing (also referred to as a linkage computing) for each control clock (CSCK). In other words, main controller 20 obtains a difference between position coordinate (X, Y, θz) and position coordinate (X', Y', θz') as shown in FIG. 12, and furthermore obtains a moving average MA_K {(X, Y, θz) - (X', Y', θz')} of the difference for a predetermined clock number K, which is held as a coordinate offset O. In FIG. 12, the calculation of the moving average is indicated by reference code MA_K.

[0100] Incidentally, moving average MA_K (X, Y, θz) and MA_K (X', Y', θz') can be obtained for a predetermined clock number K with respect to position coordinate (X, Y, θz) and the position coordinate (X' Y', θz'), respectively, and a difference MA_K(X, Y, θz) - MA_K(X', Y', θz') can be held as coordinate offset O.

[0101] Main controller 20 performs a linkage process in the case of switching. In other words, main controller 20 adds the coordinate offset O held at the time of the second control clock just before to position coordinate (X', Y', θz') of wafer stage WST1 computed from the measurement values of encoders Enc2, Enc3, and Enc4 at the time of the third control clock, so that the position coordinate coincides with a position coordinate (X, Y, θ z) of wafer stage WST1 computed by the measurement values of encoders Enc1, Enc2, and Enc3 at the time of the control clock just before (in this case, the time of the second control clock). The position coordinate {(X', Y', θz') +O} to which offset cancellation has been applied is substituted in one of the formulas (1) to (4) that the measurement values of encoder Enc4 follow, so as to compute the measurement values of encoder Enc4, which are set as the measurement values of Enc4. FIG. 12 shows this linkage process as code CH.

[0102] When the linkage process above is performed, it should be confirmed that the value of coordinate offset O is sufficiently stable for the most recent predetermined clock number. Furthermore, as is previously described, position coordinate (X, Y, θ z) of wafer stage WST1 computed from the measurement values of encoder system 70 fluctuates minutely with respect to the true position by measurement errors due to the production error of the scale and the like. Therefore, the linkage process should be performed at a timing (at the time of clock generation) where the difference between position coordinate (X, Y, θz) of wafer stage WST1 computed from the measurement values of encoders Enc1, Enc2, and Enc3 and position coordinate (X Y', θz') of wafer stage WST1 computed from the measurement values of encoders Enc2, Enc3, and Enc4 coincides or almost coincides with coordinate offset O which is sufficiently stable.

[0103] By the linkage process described so far, the continuity of the position coordinate of the wafer stage computed before and after the switching is secured, as shown in FIG. 11(B).

[0104] Incidentally, the linkage process is not limited to the case of correcting the measurement values of the heads after switching as described above, and such other process can also be employed. For example, other methods can also be applied, such as driving (performing position control of) the wafer stage while adding an offset to the current position or the target position of the wafer stage with the measurement errors serving as an offset, or correcting the reticle position only by the measurement error.

[0105] After the time of the fourth control clock in FIG. 12 after the switching, main controller 20 outputs position coordinate (X', Y', θz') computed from the measurement values of encoders Enc2, Enc3, and Enc4 to wafer stage drive system 27 as a stage coordinate for servo control, and drives and controls wafer stage WST1.

[0106] Incidentally, in the first switching described above, the head to be used was switched after scanning exposure of the fourth area S_4 within area B_0 was performed, before the step movement to the fifth shot area S_5 within area B_2 is performed. Now, in the arrangement of the shot area on wafer W_1 shown in FIG. 7, the third shot area S_3 is also included in area B_0 as shown in FIG. 9. Therefore, as shown in FIG. 10(C), the head to be used can be switched after scanning exposure of the third area S_3 within area B_0 has been performed, before the step movement to the fourth shot area S_4 is performed. In this case, after the scanning exposure of the third shot area S_3 has been performed driving wafer stage WST1 in a constant manner for a part of the scanning exposure section Q1' with respect to shot area S_3, concurrently with the linkage computing described above being performed, the heads to be used are switched from heads 60_4, 60_1, and 60_2 to heads 60_1, 60_2, and 60_3 when wafer stage WST1 passes through a switching occurrence position P_1' on the -Y side of the third shot area S_3 at a constant speed. In such case, main controller 20 resets measurement value C_3 of head 60_3 which is to be newly used after the linkage process, or in other words, after the switching, using coordinate offset O which is obtained by the linkage computing, so that the continuity of the measurement results of the position of wafer stage WST1 before and after the switching is secured.

[0107] Similar to the first switching described above, after exposure center P performs exposure processing on the seventh shot area S_7 to the tenth shot area S_{10} and has moved from area B_2 to area B_0, switching of the head (a second switching) occurs when exposure processing of the eleventh shot area S_{11} within area B_0 is performed and exposure center P is stepped to the twelfth shot area S_{12} within area B_1. In this case, the heads to be used are switched from heads 60_1, 60_2, and 60_3 to heads 60_4, 60_1, and 60_2.

[0108] Next, when a step-and-scan exposure is performed of the 15th shot area S_{25} to the 22nd shot area S_{22} lined in the X-axis direction in the center of the Y axis direction on wafer W_1, exposure center P moves between areas B_1 and B_4 or areas B_2 and B_3, via area B_0. Switching of the head (the third to the eleventh switching) occurs herein. When exposure center P moves between areas B_1 and B_4 via area B_0, the head to be used is switched between heads 60_4, 60_1, and 60_2 and heads 60_3, 60_4, and 60_1, and when exposure center P moves between areas B_2 and B_3, the head to be used is switched between heads 60_1, 60_2, and 60_3 and heads 60_2, 60_3, and 60_4.

[0109] FIG. 10 (D) shows an enlarged view of the inside of circle C_2 in FIG. 9, which is a view used to explain the details of the eighth and ninth switching, representing the third to the eleventh switching. As it can be seen from FIG. 10(D), the 20th shot area S_{20} and the 21st shot area S_{21} (and other shot areas; the 15th shot area S_{15} to the 19th shot area S_{19}, and the 22nd shot area S_{22}) are located in area B_0. The track of exposure center P steps over area B_0, and spreads out to areas B_2 and B_3. In other words, exposure center P steps over area B_0, and moves back and forth areas B_2 and B_3.

[0110] After the 19_{th} shot area S_{19} has been exposed, main controller 20 drives (controls the position of) wafer stage WST1 based on the measurement results of heads 60_2, 60_3, and 60_4 (encoders 70_2, 70_3, and 70_4), and performs a step movement of exposure center P toward the 20th shot area S_{20} along a path shown in a U-shape indicated by a broken line in FIG. 10(D).

[0111] When exposure center P reaches acceleration starting position during the step movement, main controller 20 starts acceleration (synchronous drive) of wafer stage WST1 (wafer W_1) and reticle stage RST (reticle R). The velocity of both stages WST1 and RST becomes constant, after an acceleration time (T_a) has passed from the beginning of the acceleration.

[0112] Furthermore, during exposure time (T_c) after settling time (T_b), main controller 20 drives wafer stage WST1 in a constant manner, based on measurement results of heads 60_2, 60_3, and 60_4 (encoders 70_2, 70_3, and 70_4). This allows exposure center P to move in a constant velocity movement along a straight line path (scanning exposure path) indicated using a solid line in FIG. 10(D). In other words, exposure area IA (exposure center P) moves in a constant velocity from the +Y edge to the -Y edge of shot area S_{20}, and scanning exposure of shot area S_{20} is performed.

[0113] In parallel with the scanning exposure of shot area S_{20} described above, or to be exact, in parallel with driving wafer stage WST1 in a constant manner for a part Q_2 of the scanning exposure path with respect to shot area S_{20}, main controller 20 performs the linkage computing previously described. After scanning exposure of the 20th shot area S_{20} has been performed, main controller 20 switches the heads to be used from heads 60_2, 60_3, and 60_4 to heads 60_1, 60_2, and 60_3 when wafer stage WST1 passes through a switching occurrence position P_2 on the -Y side of the 20th shot area S20 at a constant speed. Here, main controller 20 resets measurement value C_1 of head 60_1 which is to be newly used after the linkage process previously described, or in other words, after the switching, using coordinate offset O which is obtained by the linkage computing, so that the continuity of the measurement results of the position of wafer stage WST1 before and after the switching is secured.

[0114] After the switching, main controller 20 drives (controls the position of) wafer stage WST1 based on the measurement results of heads 60_1, 60_2, and 60_3 (encoders 70_1, 70_2, and 70_3), and performs a step movement toward the next shot area S_{21}. In this case, exposure center P draws a U-shaped track from the -Y edge of shot area S_{20} and retreats to area B_2 once, and then returns to area B_0 and moves toward the next shot area S_{20}.

[0115] When exposure center P reaches acceleration starting position during the step movement, main controller 20 starts acceleration (synchronous drive) of wafer stage WST1 (wafer W_1) and reticle stage RST (reticle R).

[0116] Then, after acceleration time T_a and settling time T_b have passed from the beginning of the acceleration. main controller 20 drives wafer stage WST1 in a constant manner along the straight line path (scanning exposure path) indicated by a solid line in FIG. 10(D), based on the measurement results of heads 60_1, 60_2, and 60_3 (encoders 70_1, 70_2, and 70_3). This allows exposure area IA (exposure center P) to move at a constant velocity from the -Y edge to the +Y edge of shot area S_{21}, and scanning exposure of shot area S_{21} is performed.

[0117] In parallel with the scanning exposure of shot area S_{21} described above, or to be exact, in parallel with driving wafer stage WST1 in a constant manner for a part Q_3 of the scanning exposure path with respect to shot area S_{21}, main controller 20 performs the linkage computing previously described. After scanning exposure of the 21st shot area S_{21} has been performed, main controller 20 switches the heads to be used from heads 60_1, 60_2, and 60_3 to heads 60_2, 60_3, and 60_4 when wafer stage WST1 passes through a switching occurrence position P_3 on the +Y side of the 21st shot area S_{21} at a constant speed. Here, main controller 20 resets measurement value C_4 of head 60_4 which is to be newly used after the linkage process previously described, or in other words, after the switching, using coordinate offset O which is obtained by the linkage computing, so that the continuity of the measurement results of the position of wafer stage WST1 before and after the switching is secured.

[0118] After the switching, main controller 20 drives (controls the position of) wafer stage WST1 based on the measurement results of heads 60_2, 60_3, and 60_4 (encoders 70_2, 70_3, and 70_4), and performs a step movement toward the next shot area S_{22}. In this case, exposure center P draws a U-shaped track from the +Y edge of shot area S_{21} and retreats to area B_3 once, and then returns to area B_0 and moves toward the next shot area S_{22}.

[0119] Next, after exposure center P performs exposure processing on the 23rd shot area S_{23} to the 26th shot area S_{26} and has moved from area B_3 to area B_0, switching of the head (a twelfth switching) occurs when exposure processing of the 27th shot area S_{27} within area B_0 is performed and exposure center P is stepped to the 28th shot area S_{28} within area B_4. In this case, the heads to be used are switched from heads 60_2, 60_3, and 60_4 to heads 60_3, 60_4, and 60_1. The details are similar to the first switching previously described.

[0120] Similarly, after exposure center P performs exposure processing on the 31st shot area S_{31} to the 33rd shot area S_{33} and has moved from area B_4 to area B_0, switching of the head (a thirteenth switching) occurs when exposure processing of the 34th shot area S_{34} within area B_0 is performed and exposure center P is stepped to the 35th shot area S_{35} within area B_3. In this case, the heads to be used are switched from heads 60_3, 60_4, and 60_1 to heads 60_2, 60_3, and 60_4. The details in this case are also similar to the first switching previously described.

[0121] Due to the switching procedure and the linkage process described above, because switching of the heads do not occur during the scanning exposure of each shot area on the wafer in the exposure operation by the step-and-scan method, sufficient overlay accuracy is maintained, and a stable exposure processing of the wafer can be realized. Further, because the linkage computing is performed while wafer stage WST1 (WST2) moves at a constant speed during the scanning exposure, and the linkage process and the switching of the heads are performed using the results right after the scanning exposure, the continuity of the position measurement results of the wafer stage before and after the switching of the heads is secured.

[0122] Next, as a second example, an exposure operation with respect to wafer W_2 shown in FIG. 13 will be described. In this case, on wafer W_2, a total of 38 shot areas S_1 to S_{38}, which are arranged in an odd number in the X-axis direction and an even number in the Y-axis direction, are to be arranged, as is shown enlarged in FIG. 14.

[0123] An exposure by the step-and-scan method is performed with respect to wafer W2, along a path shown in FIG. 15. In FIG. 15, overlapping the path, areas B0 to B4 corresponding to the set of heads that face scale plate 21 when wafer stage WST1 is located at the position of exposure center P on the path and the occurrence place of the switching of the heads are shown. The notation in FIG. 15 is similar to the notation in FIG. 9.

[0124] First of all, after exposure center P performs exposure processing on the first shot area S_1 and has moved from area B_1 to area B_0, switching of the head (a first switching) occurs when exposure processing of the second shot area S_2 within area B_0 is performed and exposure center P is stepped to the third shot area S_3 within area B_2. Now, as is previously described, when exposure center P is located in areas B_1, B_0, and B_2, heads 60_4, 60_1, and 60_2, all of the heads 60_1 to 60_4, heads 60_1, 60_2, and 60_3 face scale plate 21, respectively. Accordingly, in the first switching, the heads to be used are switched from heads 60_4, 60_1, and 60_2 to heads 60_1, 60_2, and 60_3. The details are similar to the first switching with respect to wafer W_1 in the first example previously described.

[0125] Similar to the first switching described above, after exposure center P performs exposure processing on the fourth shot area S_4 to the sixth shot area S_6 and has moved from area B_2 to area B_0, switching of the head (a second switching) occurs when exposure processing of the seventh shot area S_7 within area B_0 is performed and exposure center P is stepped to the eighth shot area S_8 within area B_1. In this case, the heads to be used are switched from heads 60_1, 60_2, and 60_3 to heads 60_4, 60_1, and 60_2.

[0126] Next, when a step-and-scan exposure is performed of the 11th shot area S_{11} to the 19th shot area S_{19} lined in the X-axis direction in the center of the Y axis direction (the third row) on wafer W_2, exposure center P moves between areas B_1 and B_4 or areas B_2 and B_3, via area B_0. Switching of the head (the third to the tenth switching) occurs herein. Similarly, when a step-and-scan exposure is performed of the 20th shot area S_{20} to the 28th shot area S_{28} lined in the X-axis direction in the fourth row, exposure center P moves between areas B_1 and B_4 or areas B_2 and B_3, via area B_0. Switching of the head (the eleventh to the eighteenth switching) occurs herein. When exposure center P moves between areas B_1 and B_4 via area B_0, the head to be used is switched between heads 60_4, 60_1, and 60_2 and heads 60_3, 60_4, and 60_1, and when exposure center P moves between areas B_2 and B_3, the head to be used is switched between heads 60_1, 60_2, and 60_3 and heads 60_2, 60_3, and 60_4.

[0127] FIG. 16 (A) shows an enlarged view of the inside of circle C_3 in FIG. 15, which is a view used to explain the details of the third and fourth switching, representing the third to the eighteenth switching. As it can be seen from FIG. 16 (A), the eleventh shot area S_{11} and the twelfth shot area $S1_2$ are located on the border of area B_0 and area B_1. The track of exposure center P steps over area B_0, and spreads out to areas B_1 and B_4. In other words, exposure center P steps over area B_0, and moves back and forth areas B_1 and B_4.

[0128] In this example, because the shot area subject to exposure is not completely included in area B_0, the detailed procedure of the third and the fourth switching differs to some extent from the detailed procedure of the eighth and the ninth switching of wafer W_1 previously described. Therefore, details of the third and the fourth switching will be described, placing an emphasis on the difference.

[0129] After the tenth shot area S_{10} has been exposed, main controller 20 drives (controls the position of) wafer stage WST1 based on the measurement results of heads 60_4, 60_1, and 60_2 (encoders 70_4, 70_1, and 70_2), and performs a step movement of exposure center P toward the acceleration starting position for exposure of the eleventh shot area S_{11} along a path indicated by a broken line in FIG. 15.

[0130] After the step movement, main controller 20 starts the acceleration synchronous drive of wafer stage WST1 (wafer W1) and reticle stage RST (reticle R) . The velocity of both stages WST1 and RST becomes constant, after an acceleration time (T_a) has passed from the beginning of the acceleration.

[0131] Furthermore, during exposure time (T_c) After settling time (T_b), main controller 20 drives wafer stage WST1 in a constant manner, based on measurement results of heads 60_4, 60_1, and 60_2 (encoders 70_4, 70_1, and 70_2). This allows exposure center P to move in a constant velocity movement along a straight line path (scanning exposure path) indicated using a solid line in FIG. 16 (A). In other words, exposure area IA (exposure center P) moves at a constant velocity from the -Y edge to the +Y edge of shot area S_{11}, and scanning exposure of shot area S_{11} is performed.

[0132] In parallel with the scanning exposure of shot area S_{11} previously described, or to be exact, in parallel with driving wafer stage WST1 in a constant manner for a part Q_5 of the scanning exposure path with respect to shot area S_{11}, main controller 20 performs the linkage computing previously described, like the eighth and ninth switching with respect to wafer W_1 previously described. After scanning exposure of the eleventh shot area S_{11} has been performed, main controller 20 switches the heads to be used from heads 60_4, 60_1, and 60_2 to heads 60_3, 60_4, and 60_1 (the third switching) when wafer stage WST1 passes through a switching occurrence position P_5 on the +Y side of the eleventh shot area S_{11} at a constant speed. Here, main controller 20 resets measurement value C_3 of head 60_3 which is to be newly used after the linkage process previously described, or in other words, after the switching, using coordinate offset O which is obtained by the linkage computing, so that the continuity of the measurement results of the position of wafer stage WST1 before and after the switching is secured.

[0133] After the switching, main controller 20 drives (controls the position of) wafer stage WST1 based on the measurement results of heads 60_3, 60_4, and 60_1 (encoders 70_3, 70_4, and 70_1), and performs a step movement toward the next shot area S_{12}. In this case, exposure center P draws a U-shaped track from the +Y edge of shot area S_{11} and retreats to area B_4 once, and then returns to area B_0 and moves toward the next shot area S_{12}.

[0134] When exposure center P reaches acceleration starting position during the step movement, main controller 20 starts acceleration (synchronous drive) of wafer stage WST1 (wafer W1) and reticle stage RST (reticle R) to perform exposure processing on shot area S_{12}. However, because shot area S_{12} is located on the border of area B_0 and area B_1, the heads need to be switched during the scanning exposure of the twelfth shot area S_{12}. Therefore, in the fourth switching, the heads to be used are switched from heads 60_3, 60_4, and 60_1 to heads 60_4, 60_1, and 60_2 before scanning exposure of the twelfth shot area S_{12} is performed.

[0135] In the fourth switching, while exposure center P performs a step movement from shot area S_{11} to shot area S_{12} along a U-shaped path prior to the switching, main controller 20 performs the linkage computing previously described concurrently with driving wafer stage WST1 in a constant manner for part of a short straight line section Q_6 which exposure center P passes during settling time T_b. Before scanning exposure of the twelfth shot area S_{12}, main controller 20 switches the heads to be used from heads 60_3, 60_4, and 60_1 to heads 60_4, 60_1, and 60_2 when wafer stage WST1 passes through a switching occurrence position P_6 on the +Y side of the twelfth shot area S_{12} at a constant speed. Here, main controller 20 resets measurement value C_2 of head 60_2 which is to be newly used after the linkage process previously described, or in other words, after the switching, using coordinate offset O which is obtained by the linkage computing, so that the continuity of the measurement results of the position of wafer stage WST1 before and after the switching is secured.

[0136] After the switching, main controller 20 moves wafer stage WST1 in a constant velocity along a straight line path (scanning exposure path) indicated by a solid line in FIG. 16(A), according to the measurement results of heads 60_4, 60_1, and 60_2 (encoders 70_4, 70_1, and 70_2). This allows exposure area IA (exposure center P) to move at a constant velocity from the +Y edge to the -Y edge of shot area S_{12}, and scanning exposure of shot area S_{12} is performed.

[0137] However, because the distance (distance of straight line section Q_6) in which wafer stage WST1 is driven at a constant speed is short in the linkage computing during settlement time T_b, a coordinate offset O which is sufficiently stable may not be obtained.

[0138] In order to prevent such a situation from occurring, as a first method for securing enough time for linkage computing (to obtain a sufficiently stable coordinate offset O), performing the linkage computing previously described while wafer stage WST1 is accelerated can be considered, or in other words, performing the linkage computing during the step movement of exposure center P toward shot area S_{12} along a U-shaped path in FIG. 16(A), concurrently with driving wafer stage WST1 for a long curve section Q_6' which is passed during acceleration time Ta (or a deceleration overscan time T_a and acceleration time T_a). However, at this point, because wafer stage WST1 is accelerated, an error may occur on stage position measurement by encoder system 70.

[0139] In other words, as shown in FIG. 17(A), with encoder system 70 in the embodiment, a measurement beam is irradiated from head 60_1 in parallel to the Z-axis, on scale plate 21 (22) facing head 60_1 installed in wafer stage WST1. However, for example, when an acceleration in a direction (the -X direction) shown by an arrow in FIG. 17 (B) is applied to wafer stage WST1, the setting position of encoder head 60_1 shifts relatively to the +X direction with respect to wafer stage WST1, and the setting attitude is tilted to the θy direction. This makes the measurement beam tilt, which is irradiated on a point of scale plate 21 (22) shifted from the designed irradiation point, which in turn causes a measurement error.

[0140] Therefore, taking into consideration that there may be cases when linkage computing is performed during the acceleration time, a relation between the acceleration of wafer stage WST1 (WST2) and the measurement error of encoder system 70 (71) can be measured beforehand, and during operation of the exposure apparatus, the measurement results of encoder system 70 (71) can be corrected using the actual measurement data. Or, a measuring instrument which measures the position and tilt of heads 60_1 to 60_4 can be provided in wafer stage WST1 (WST2), and the measurement values of heads 60_1 to 60_4 can be corrected, based on measurement results of the measuring instrument.

[0141] As a second method for securing enough time for linkage computing, as shown in FIG. 16(B), a redundant section Q_6" can be provided in the stepping path so as to extend the section where wafer stage WST1 moves at a constant speed (in other words, section Q_6 in FIG. 16(A)), and the linkage computing can be performed while wafer stage WST1 is driven at a constant speed in the section.

[0142] As a third method for securing enough time for linkage computing, to condition ($B \geq b_i+L+2t$) for the configuration and placement of encoder heads 60_1 to 60_4 and scale plate 21 previously described, a condition $B \geq b_i+2La+2t$ can be considered to be added (in other words, change to condition $B \geq b_i + \mathrm{Max}(L, 2La) + 2t$), further taking into consideration distance La in the Y-axis direction in the U-shaped stepping section.

[0143] FIG. 16(C) shows an enlarged view of the inside of circle C4 in FIG. 15. However, in FIG. 16(C), according to condition $B \geq b_i + \mathrm{Max}(L, 2La) + 2t$ described above, area B_0 expands in the Y-axis direction. In the case of FIG. 16(C), because the U-shaped stepping section is completely included in area B_0, after shot area S_{19} has been exposed, the heads need to be switched (the tenth switching in FIG. 15) only when the wafer steps in the Y direction toward shot area S_{20}, and the third to ninth switching and the eleventh to eighteenth switching no longer are necessary.

[0144] Incidentally, condition $B \geq b_i + \mathrm{Max}(L, 2La) + 2t$ can be applied not only to a shot arrangement where an even number of shot areas are arranged in the Y-axis direction like in wafer W_2, and can also be applied to an arbitrary shot arrangement.

[0145] Next, after exposure center P performs exposure processing on the 29th shot area S_{29} to the 31st shot area S_{31} and has moved from area B_4 to area B_0, switching of the head (a nineteenth switching) occurs when exposure processing of the 32nd shot area S_{32} within area B_0 is performed and exposure center P is stepped to the 33rd shot area S_{33} within area B_3. In this case, the heads to be used are switched from heads 60_3, 60_4, and 60_1 to heads 60_2, 60_3, and 60_4. The details are similar to the first switching previously described.

[0146] Similarly, after exposure center P performs exposure processing on the 36th shot area S_{36} and has moved from area B_3 to area B_0, switching of the head (a twentieth switching) occurs when exposure processing of the 37th shot area S_{37} within area B_0 is performed and exposure center P is stepped to the 38th shot area S_{38} within area B_4. In this case, the heads to be used are switched from heads 60_2, 60_3, and 60_4 to heads 60_3, 60_4, and 60_1. The details in this case are also similar to the first switching previously described.

[0147] Due to the switching procedure and the linkage process described above, because switching of the heads do not occur during the scanning exposure of each shot area on the wafer in the exposure operation by the step-and-scan method, sufficient overlay accuracy is maintained, and a stable exposure processing of the wafer can be realized. Further, during the scanning exposure, main controller 20 performs the linkage computing while wafer stage WST1 (WST2) moves at a constant speed, and then performs the linkage process and exchange of the heads using the results immediately after the scanning exposure. Or, main controller 20 performs linkage computing while wafer stage WST1 (WST2) moves at a constant speed during the stepping movement, or performs linkage computing while correcting the acceleration during the acceleration movement, and using the measurement results, performs the linkage process and switching of the heads just before the scanning exposure. This allows the continuity of the position coordinate of the wafer stage computed before and after the switching to be secured.

[0148] Next, the principle of position measurement in directions of three degrees of freedom (Z, θx, θy) by encoder systems 70 and 71 will be further described. Here, measurement results or measurement values of encoder heads 60_1 to 60_4 or encoders 70_1 to 70_4 refer to measurement results of encoder heads 60_1 to 60_4 or encoders 70_1 to 70_9 in the Z-axis direction.

[0149] In the embodiment, by employing a configuration and an arrangement of encoder heads 60_1 to 60_4 and scale plate 21 as is previously described, at least three of the encoders head 60_1 to 60_4 face (corresponding sections 21_1 to 21_4 of) scale plate 21 according to area A_0 to A_4 where wafer stage WST1 (WST2) is located within the exposure time movement area. Effective measurement values are sent to main controller 20 from the heads (encoders) facing scale plate 21.

[0150] Main controller 20 computes the position (Z, θx, θy) of wafer stage WST1 (WST2), based on measurement results of encoders 70_1 to 70_4. Here, the measurement values (each expressed as D_1 to D_4, respectively, to distinguish the values from measurement values C_1 to C_4 in a measurement direction which is not in the Z-axis direction as is previously described, namely, in a uniaxial direction in the XY plane) of encoders 70_1 to 70_4 in the Z-axis direction depend upon the position (Z, θx, θy) of wafer stage WST1 (WST2) as in formulas (5) to (8) below.

$$D_1 = -p\tan\theta y + p\tan\theta x + Z \ \ldots \ (5)$$

$$D_2 = p\tan\theta y + p\tan\theta x + Z \ \ldots \ (6)$$

$$D_3 = p\tan\theta y - p\tan\theta x + Z \ \ldots \ (7)$$

$$D_4 = -p\tan\theta y - p\tan\theta x + Z \ \ldots \ (8)$$

[0151] However, p is the distance (refer to FIG. 5) of the head in the X-axis and the Y-axis directions from the center of wafer table WTB1 (WTB2).

[0152] Main controller 20 selects the formulas that the measurement values of the three heads (encoders) follow according to areas A_0 to A_4 where wafer stage WST1 (WST2) is positioned from formula (5) to (8) described above, and by substituting and solving the measurement values of the three heads (encoders) into the simultaneous equation built from the three formulas which were selected, the position (Z, θx, θy) of wafer stage WST1 (WST2) is computed. For example, when wafer stage WST1 (or WST2) is located in the first area A_1, main controller 20 forms a simultaneous equation from formulas (5), (6) and (8) that measurement values of heads 60_1, 60_2, and 60_4 (encoders 70_1, 70_2, and 70_4) follow, and solves the simultaneous equation by substituting the measurement values into the left side of formulas (5), (6) and (8), respectively.

[0153] Incidentally, in the case wafer stage WST1 (WST2) is located in the 0th area A_0, three heads from heads 60_1 to 60_4 (encoders 70_1 to 70_4) can be randomly selected, and a simultaneous equation made from the formulas that the measurement values of the selected three heads follow can be used.

[0154] Based on the computation results (Z, θx, θy) above and step information (focus mapping data) previously described, main controller 20 performs a focus leveling control on wafer stage WST1 (WST2) within the exposure time movement area.

[0155] In the case wafer stage WST1 (or WST2) is located within measurement time movement area, main controller 20 measures the positional information in directions of three degrees of freedom (Z, θx, θy), using encoder system 70 or 71. The measurement principle and the like, here, is the same as in the case when wafer stage WST1 is located within the exposure time movement area previously described, except for the point where the exposure center is replaced with the detection center of alignment system ALG, and (sections 21_1 to 21_4 of) scale plate 21 is replaced with (sections 22_1 to 22_4 of) scale plate 22. Based on the measurement results of encoder system 70 or 71, main controller 20 performs a focus leveling control on wafer stage WST1 (WST2). Incidentally, in the measurement time movement area (measurement station), focus leveling does not necessarily have to be performed. In other words, a mark position and the step information (focus mapping data) should be obtained in advance, and by deducting the Z tilt of the wafer stage at the time of obtaining the step information from the step information, the step information of the reference surface of the wafer stage, such as the step information with the upper surface serving as the reference surface, should be obtained. And, at the time of exposure, focus leveling becomes possible based on the positional information in directions of three degrees of freedom (Z, θx, θy) of this step information and (the reference surface of) the wafer surface.

[0156] Furthermore, main controller 20 switches and uses three heads that include at least one different head out of heads 60_1 to 60_4 that face scale plates 21 and 22, according to the position of wafer stages WST1 and WST2. In this case, when an encoder head is switched, the linkage process similar to the one previously described is performed to secure the continuity of the measurement results of the position of wafer stage WST1 (or WST2).

[0157] As discussed in detail above, in exposure apparatus 100 of the embodiment, encoder systems 70 and 71 are provided which measure the positional information of wafer stages WST1 and WST2 in directions of six degrees of freedom (X, Y, Z, θx, θy, and θz) by irradiating measurement beams from the four heads 60_1 to 60_4 installed in wafer stages WST1 and WST2 on scale plate 21 that covers the movable range of wafer stages WST1 and WST2 except for the area right below projection optical system PL (alignment system ALG). And, placement distances A and B of heads 60_1 to 60_4 are each set to be larger than width a_1 and b_1 of the opening of scale plates 21 and 22, respectively. This allows the positional information of wafer stages WST1 and WST2 to be obtained (measured), by switching and using the three heads facing scale plates 21 and 22 out of the four heads 60_1 to 60_4 according to the position of wafer stages WST1 and WST2.

[0158] Furthermore, with exposure apparatus 100 of the embodiment, placement distances A and B of heads 60_1 to 60_1 are each set larger than the sum of width a_i and b_i of the opening of scale plates 21 and 22 and width W and L of the shot area. This allows the positional information of wafer stages WST1 and WST2 to be obtained without the heads 60_1 to 60_4 being switched, while wafer stages WST1 and WST2 which hold a wafer for exposure of the wafer is scanned (in constant velocity) and driven. Accordingly, the pattern can be formed on the wafer with good accuracy, and especially for exposure from the second layer onward, the overlay accuracy can be maintained with high precision.

[0159] Further, in exposure apparatus 100 of the embodiment, by using the measurement results of the positional information of wafer stages WST1 and WST2 measured by the four heads 60_1 to 60_4, wafer stages WST1 and WST2 holding the wafer are scanned (in constant velocity) and driven to expose the shot areas subject to exposure on the wafer, and after the drive, three heads which make a set used for measuring the positional information from the four heads 60_1 to 60_4 are switched to another set (including at least one different head), according to the position of wafer stages WST1 and WST2. Or, by using the measurement results of the positional information, wafer stages WST1 and WST2 are driven and stepped to a starting point of scanning (in constant velocity) for the shot areas subject to exposure, and after the stepping movement, before wafer stages WST1 and WST2 are scanned (in constant velocity) and driven to expose the shot areas subject to exposure, the heads which make a set used for measuring the positional information from the four heads 60_1 to 60_4 are switched to another set (including a different head). This allows the positional information of wafer stages WST1 and WST2 to be obtained without the heads 60_1 to 60_4 being switched, while wafer stages WST1 and WST2 which hold a wafer for exposure of the wafer is scanned (in constant velocity) and driven. Accordingly, the pattern can be formed on the wafer with good accuracy, and especially for exposure from the second layer onward, the overlay accuracy can be maintained with high precision.

[0160] Incidentally, in the embodiment above, at least one auxiliary head can be provided in the vicinity of each of the heads on the four corners of the upper surface of the wafer table, and in the case a measurement abnormality occurs in the main heads, the measurement can be continued by switching to the auxiliary head nearby.

[0161] Incidentally, in the embodiment above, while the case where two-dimensional diffraction grating RG was formed on the lower surface of sections 21_1 to 21_4 of scale plate 21 and sections 22_1 to 22_4 of scale plate 22 was described as an example, besides this, the embodiment described above can also be applied in the case where a one-dimensional diffraction grating whose periodic direction is only in the measurement direction (in a uniaxial direction within the XY plane) of the corresponding encoder heads 60_1 to $6O_4$ is formed.

[0162] Further, in the embodiment above, as each of the heads 60_1 to 60_4 (encoders 70_1 to 70_4), while the case has been described where a two-dimensional encoder whose measurement direction is in a uniaxial direction within the XY plane and in the Z-axis direction was employed as an example, besides this, a one-dimensional encoder whose measurement direction is in a uniaxial direction within the XY plane and a one-dimensional encoder (or a surface position sensor and the like of a non-encoder method) whose measurement direction is in the Z-axis direction can also be employed. Or, a two-dimensional encoder whose measurement direction is in two axial directions which are orthogonal to each other in the XY plane can be employed. Furthermore, a three-dimensional encoder (3 DOF sensor) whose measurement direction is in the X-axis, the Y-axis, and the Z-axis direction can also be employed.

[0163] Incidentally, in the embodiment described above, while the case has been described where the exposure apparatus is a scanning stepper, the present invention is not limited to this, and the embodiment described above can also be applied to a static exposure apparatus such as a stepper. Even in the case of a stepper, by measuring the position of a stage on which the object subject to exposure is mounted using an encoder, position measurement error caused by air fluctuation can substantially be nulled, which is different from when measuring the position of this stage by an interferometer, and it becomes possible to position the stage with high precision based on the measurement values of the encoder, which in turn makes it possible to transfer a reticle pattern on the wafer with high precision. Further, the embodiment described above can also be applied to a projection exposure apparatus by a step-and-stitch method that synthesizes a shot area and a shot area. Moreover, the embodiment described above can also be applied to a multi-stage type exposure apparatus equipped with a plurality of wafer stages, as is disclosed in, for example, U.S. Patent No. 6,590,634, U.S. Patent No. 5,969,441, U.S. Patent No. 6,208,407 and the like. Further, the embodiment described above can also be applied to an exposure apparatus which is equipped with a measurement stage including a measurement member (for example, a reference mark, and/or a sensor and the like) separate from the wafer stage, as disclosed in, for example, U.S. Patent Application Publication No. 2007/0211235, and U.S. Patent Application Publication No. 2007/0127006 and the like.

[0164] Further, the exposure apparatus in the embodiment above can be of a liquid immersion type, like the ones disclosed in, for example, PCT International Publication No. 99/49504, U.S. Patent Application Publication No. 2005/0259234 and the like.

[0165] Further, the magnification of the projection optical system in the exposure apparatus of the embodiment above is not only a reduction system, but also may be either an equal magnifying system or a magnifying system, and projection optical system PL is not only a dioptric system, but also may be either a catoptric system or a catadioptric system, and in addition, the projected image may be either an inverted image or an upright image.

[0166] In addition, the illumination light IL is not limited to ArF excimer laser light (with a wavelength of 193 nm), but may be ultraviolet light, such as KrF excimer laser light (with a wavelength of 248 nm), or vacuum ultraviolet light, such as F_2 laser light (with a wavelength of 157 nm). As 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 as vacuum ultraviolet light, 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.

[0167] Further, in the embodiment above, a transmissive type mask (reticle) is used, which is a transmissive substrate on which a predetermined light shielding pattern (or a phase pattern or a light attenuation pattern) is formed. Instead of this reticle, however, as is disclosed in, for example, U.S. Patent No. 6,778,257 description, an electron mask (which is also called a variable shaped mask, an active mask or an image generator, and includes, for example, a DMD (Digital Micromirror Device) that is a type of a non-emission type image display device (spatial light modulator) or the like) on which a light-transmitting pattern, a reflection pattern, or an emission pattern.is formed according to electronic data of the pattern that is to be exposed can also be used. In the case of using such a variable shaped mask, because the stage where a wafer, a glass plate or the like is mounted is scanned with respect to the variable shaped mask, an equivalent effect as the embodiment above can be obtained by measuring the position of the stage using an encoder.

[0168] Further, as is disclosed in, for example, PCT International Publication No. 2001/035168, the embodiment above can also be applied to an exposure apparatus (lithography system) that forms line-and-space patterns on a wafer W by forming interference fringes on wafer W.

[0169] Moreover, as disclosed in, for example, U.S. Patent No. 6,611,316, the embodiment above can also be applied to an exposure apparatus that synthesizes two reticle patterns via a projection optical system and almost simultaneously performs double exposure of one shot area by one scanning exposure.

[0170] 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 other objects such as a glass plate, a ceramic substrate, a film member, or a mask blank.

[0171] The application of the exposure apparatus is not limited to an exposure apparatus for fabricating semiconductor devices, but can be widely adapted to, for example, an exposure apparatus for fabricating liquid crystal devices, wherein a liquid crystal display device pattern is transferred to a rectangular glass plate, as well as to exposure apparatuses for fabricating organic electroluminescent displays, thin film magnetic heads, image capturing devices (e.g., CCDs), micromachines, and DNA chips. Further, the embodiment described above can be applied not only to an exposure apparatus for producing microdevices such as semiconductor devices, but can also be applied to an exposure apparatus that transfers a circuit pattern onto a glass plate or silicon wafer to produce a mask or reticle used in a light exposure apparatus, an EUV exposure apparatus, an X-ray exposure apparatus, an electron-beam exposure apparatus, and the like.

[0172] Incidentally, the disclosures of all publications, the Published PCT International Publications, the U.S. Patent Applications and the U.S. Patents that are cited in the description so far related to exposure apparatuses and the like are each incorporated herein by reference.

[0173] Incidentally, electronic devices such as a semiconductor are manufactured through the steps of; a step where the function/performance design of the device is performed, a step where a reticle based on the design step is manufactured, a step where a wafer is manufactured from silicon materials, a lithography step where the pattern formed on a mask is transferred onto an object such as the wafer by the exposure apparatus in the embodiment above, a development step where the wafer that has been exposed is developed, an etching step where an exposed member of an area other than the area where the resist remains is removed by etching, a resist removing step where the resist that is no longer necessary when etching has been completed is removed, a device assembly step (including a dicing process, a bonding process, the package process), inspection steps and the like. In this case, because the exposure apparatus and the exposure method in the embodiment above is used in the lithography step, devices having high integration can be produced with good yield.

[0174] Further, the exposure apparatus (pattern formation apparatus) of the embodiment above is manufactured by assembling various subsystems, which include the respective constituents that are recited in the claims of the present application, so as to keep predetermined mechanical accuracy, electrical accuracy and optical accuracy. In order to secure these various kinds of accuracy, before and after the assembly, adjustment to achieve the optical accuracy for various optical systems, adjustment to achieve the mechanical accuracy for various mechanical systems, and adjustment to achieve the electrical accuracy for various electric systems are performed. A process of assembling various subsystems into the exposure apparatus includes mechanical connection, wiring connection of electric circuits, piping connection of pressure circuits, and the like among various types of subsystems. Needless to say, an assembly process of individual subsystem is performed before the process of assembling the various subsystems into the exposure apparatus. When the process of assembling the various subsystems into the exposure apparatus is completed, a total adjustment is performed and various kinds of accuracy as the entire exposure apparatus are secured. Incidentally, the making of the exposure apparatus is preferably performed in a clean room where the temperature, the degree of cleanliness and the like are controlled.

Industrial Applicability

[0175] As is described above, the exposure apparatus and the exposure method of the present invention are suitable for exposing an object. Further, the device manufacturing method of the present invention is suitable for manufacturing electron devices such as semiconductor devices or liquid crystal display devices.
The following numbered paragraphs set out particular combinations of features which are considered relevant to particular embodiments of the present disclosure.

1. An exposure apparatus which sequentially exposes an energy beam on a plurality of divided areas placed in a shape of a matrix on an object, and forms a pattern on each of the plurality of divided areas, the apparatus comprising:

    a movable body which holds the object and moves along a predetermined plane;
    a position measurement system which has a plurality of heads provided on the movable body, and of the plurality of heads, obtains a positional information of the movable body, based on measurement results of a predetermined number of heads which irradiate a measurement beam on a measurement plane that has an opening partially and is placed facing the movable body and roughly parallel to the predetermined plane, receive a return beam from the measurement plane, and measure a position of the movable body in each measurement direction; and
    a control system which drives the movable body based on the positional information obtained by the position measurement system, and also switches at least one of the predetermined number of heads used to compute a positional information of the movable body according to a position of the movable body to a different head, wherein
    of the plurality of heads, a separation distance of two heads set apart in a first direction within the predetermined plane is larger than a width of the opening in the first direction.

2. The exposure apparatus according to Paragraph 1 wherein
the separation distance of the two heads set apart in the first direction is larger than a sum of the width of the opening in the first direction and a width of each of the plurality of divided areas in the first direction.

3. The exposure apparatus according to one of Paragraphs 1 and 2 wherein
of the plurality of heads, a separation distance of two heads set apart in a second direction which is perpendicular to the first direction within the predetermined plane is larger than a width of the opening in the second direction.

4. The exposure apparatus according to Paragraph 3 wherein

the separation distance of the two heads set apart in the second direction is larger than a sum of the width of the opening in the second direction and a width of each of the plurality of divided areas in the second direction.

5. The exposure apparatus according to any one of Paragraphs 1 to 4 wherein
the measurement plane is configured of a plurality of sections where each of the plurality of heads faces.

6. The exposure apparatus according to any one of Paragraphs 1 to 5 wherein
on the measurement plane, a two-dimensional grating whose periodic direction is in two axial directions that are perpendicular to each other within the predetermined plane is formed.

7. The exposure apparatus according to Paragraph 6 wherein
at least one of the two axial directions serves as a measurement direction for each of the plurality of heads.

8. The exposure apparatus according to any one of Paragraphs 1 to 7 wherein
at least a direction perpendicular to the predetermined plane serves as a measurement direction for each of the plurality of heads.

9. The exposure apparatus according to any one of Paragraphs 1 to 8 wherein
the control system performs a drive at a constant speed of the movable body in the first direction to form the pattern in a divided area subject to formation of the plurality of divided areas based on the positional information obtained by the position measurement system, and after the drive at a constant speed, steps and drives the movable body toward a starting point of a constant speed drive to form the pattern with respect to a next divided area subject to formation of the plurality of divided areas.

10. The exposure apparatus according to Paragraph 9 wherein
the control system switches a head used to compute a positional information of the movable body, after performing the drive at a constant speed.

11. The exposure apparatus according to Paragraph 10 wherein
the control system makes an offset to reset a measurement result of a head to be used after the switching using the measurement results of the plurality of heads during the drive at a constant speed, and resets the measurement results of the heads using the offset.

12. The exposure apparatus according to any one of Paragraphs 1 to 11 wherein
the control system steps and drives the movable body toward a starting point of a constant speed drive to form the pattern in a divided area subject to formation of the plurality of divided areas, based on the positional information obtained by the position measurement system, and after the step and drive, performs a drive at a constant speed of the movable body in the first direction from the starting point to form the pattern in the divided area subject to formation.

13. The exposure apparatus according to Paragraph 12 wherein
the control system switches a head used to compute a positional information of the movable body, before performing the drive at a constant speed.

14. The exposure apparatus according to Paragraph 13 wherein
the control system makes an offset to reset a measurement result of a head to be used after the switching using the measurement results of the plurality of heads prior to the switching of the heads, and resets the measurement results of the heads using the offset.

15. The exposure apparatus according to Paragraph 14 wherein
the control system corrects measurement errors of the plurality of heads that occur due to acceleration of the movable body.

16. The exposure apparatus according to one of Paragraphs 14 and 15 wherein
the control system sets a redundant section in a path of the step and drive, and makes the offset while the movable body moves at a constant speed in the redundant section.

17. The exposure apparatus according to any one of Paragraphs 14 to 16 wherein

the separation distance of the two heads set apart in the first direction is larger than a sum of the width of the opening in the first direction and two times the distance in the first direction of the step and drive.

18. The exposure apparatus according to any one of Paragraphs 12 to 17, the apparatus further comprising:

a mask stage which holds a mask that is an original plate on which the pattern is formed, wherein
the control system drives the mask stage in the first direction synchronously, when performing the drive at a constant speed of the movable body in the first direction.

19. The exposure apparatus according to any one of Paragraphs 1 to 18, the apparatus further comprising:

a mark detection system which detects a mark formed on the object; and
a separate position measurement system which obtains a positional information of the movable body based on measurement results of a predetermined number of heads that irradiate a measurement beam on a separate measurement plane, which is placed facing the movable body roughly in parallel with the predetermined plane and corresponding to the mark detection system and has an opening partially, receive a return beam from the measurement plane, of the plurality of heads.

20. The exposure apparatus according to Paragraph 19 wherein
the separate measurement plane is configured of a plurality of sections where each of the plurality of heads faces.

21. The exposure apparatus according to any one of Paragraphs 1 to 20, the apparatus further comprising:

an optical system which emits the energy beam to the object.

22. An exposure apparatus which sequentially exposes an energy beam on a plurality of divided areas on an object, and forms a pattern on each of the plurality of divided areas on the object, the apparatus comprising:

a movable body which holds the object and moves along a predetermined plane;
a position measurement system which has a plurality of heads provided on the movable body, and of the plurality of heads, irradiates a measurement beam on a measurement plane having a measurement non-effective area in part of the measurement plane which is placed facing the movable body and roughly parallel to the predetermined plane, receives a return beam from the measurement plane, and obtains a positional information of the movable body based on measurement results of a predetermined number of heads which measure a position of the movable body in each measurement direction; and
a control system which drives the movable body based on the positional information obtained by the position measurement system, while switching a head to be used to compute the positional information of the movable body, wherein
of the plurality of heads, a separation distance of two heads set apart in a predetermined direction within the predetermined plane is decided, taking into consideration a size of the measurement non-effective area in the predetermined direction.

23. The exposure apparatus according to Paragraph 22 wherein
the separation distance of the two heads set apart in the predetermined direction is larger than the size of the measurement non-effective area in the predetermined direction.

24. The exposure apparatus according to Paragraph 23 wherein
the separation distance of the two heads set apart in the predetermined direction is larger than a sum of the size in the predetermined direction of the measurement non-effective area and each of the plurality of divided areas.

25. The exposure apparatus according to any one of Paragraphs 22 to 24, the apparatus further comprising:

an optical system which emits the energy beam to the object.

26. An exposure apparatus which sequentially exposes an energy beam on a plurality of divided areas placed in a shape of a matrix on an object, and forms a pattern on each of the plurality of divided areas, the apparatus comprising:

a movable body which holds the object and moves along a predetermined plane;

a position measurement system which has a plurality of heads provided on the movable body, and of the plurality of heads, irradiates a measurement beam on a measurement plane having an opening in part of the measurement plane which is placed facing the movable body and roughly parallel to the predetermined plane, receives a return beam from the measurement plane, and obtains a positional information of the movable body based on measurement results of a predetermined number of heads which measure a position of the movable body in each measurement direction; and

a control system which drives the movable body based on positional information obtained by the position measurement system, and also switches at least one of the predetermined number of heads used to compute a positional information of the movable body according to a position of the movable body to a different head, wherein

after a constant speed movement on the movable body is performed in a first area where heads included in a first head group and a second head group which has at least one different head of the plurality of heads face the measurement plane, in a first direction of the predetermined plane to form the pattern in a divided area subject to formation of the plurality of divided areas based on the positional information of the movable body which is obtained based on measurement results of the first head group, heads used to compute positional information of the movable body are switched to the second head group before the movable body moves from the first area to a second area where only the heads included in the second head group face the measurement plane.

27. The exposure apparatus according to Paragraph 26 wherein
during the constant speed movement, an offset to reset measurement results of a different head is made using measurement results of the first head group, and the measurement results of the different head is reset, using the offset.

28. The exposure apparatus according to one of Paragraphs 26 and 27 wherein
after the switching, the movable body is stepped and driven to a starting point of a constant speed movement to form the pattern in the next divided area subject to formation of the plurality of divided areas, based on the positional information of the movable body obtained from measurement results of the second head group.

29. The exposure apparatus according to any one of Paragraphs 26 to 28 wherein
after the movable body is stepped and driven in the first area to a starting point of a constant speed movement to form the pattern in a divided area subject to formation of the plurality of divided areas, based on measurement results of the positional information of the movable body obtained based on measurement results of the first head group, the movable body is moved at a constant speed in the first direction from the starting point to form the pattern in the divided area subject to formation, and before the movable body moves from the first area to the second area, heads to be used to compute a positional information of the movable body are switched to the second head group.

30. The exposure apparatus according to Paragraph 29 wherein
during the step and drive, an offset to reset measurement results of the different head is made using measurement results of the first head group, and the measurement results of the different head is reset, using the offset.

31. The exposure apparatus according to Paragraph 30 wherein
when the offset is made, measurement errors of the plurality of heads that occur due to acceleration of the movable body are corrected.

32. The exposure apparatus according to one of Paragraphs 30 and 31 wherein
the offset is made while the movable body moves at a constant speed in a redundant section in a path of the step and drive.

33. The exposure apparatus according to any one of Paragraphs 29 to 32 wherein
after the switching, the movable body is moved at a constant speed in the first direction from the starting point to form the pattern in the divided area subject to formation, using measurement results of the positional information of the movable body measured using the second head group.

34. The exposure apparatus according to any one of Paragraphs 26 to 33, the apparatus further comprising:

a mask stage which holds a mask that is an original plate on which the pattern is formed, wherein
the mask stage moves to in the first direction synchronously with the movement at a constant speed of the

movable body in the first direction.

35. The exposure apparatus according to any one of Paragraphs 26 to 34, the apparatus further comprising:

an optical system which emits the energy beam to the object.

36. An exposure method in which a plurality of divided areas placed in a shape of a matrix on an object is sequentially exposed an energy beam, and a pattern is formed on each of the plurality of divided areas, the method comprising:

obtaining a positional information of the movable body, based on measurement results of a predetermined number of heads of the plurality of heads provided on the movable body which moves along a predetermined plane holding the object, by irradiating a measurement beam on a measurement plane having an opening in part of the measurement plane which is placed facing the movable body and roughly parallel to the predetermined plane, receiving a return beam from the measurement plane, and measuring a position of the movable body in each measurement direction;
moving the movable body at a constant speed in the first direction in the predetermined plane to form the pattern in a divided area subject to formation of the plurality of divided areas, based on the positional information; and
after the movable body is moved at a constant speed, switching at least one of the predetermined number of heads used to compute a positional information of the movable body according to a position of the movable body to a different head.

37. The exposure method according to Paragraph 36 wherein
after the switching, the movable body is stepped and driven to a starting point of a constant speed movement to form the pattern in the next divided area subject to formation of the plurality of divided areas.

38. The exposure method according to one of Paragraphs 36 and 37 wherein
during the constant speed movement, an offset is made to reset a measurement result of a head to be used after the switching using the measurement results of the plurality of heads, and the measurement results of the heads are reset using the offset.

39. The exposure method according to any one of Paragraphs 36 to 38 wherein
the constant speed movement in the first direction of the movable body is performed synchronously with a movement in the first direction of a different movable body holding a mask that is an original plate of the pattern.

40. The exposure method according to any one of Paragraphs 36 to 39 wherein
irradiation of the energy beam on the object is performed via an optical system.

41. An exposure method in which a plurality of divided areas placed in a shape of a matrix on an object is sequentially exposed by an energy beam, and a pattern is formed on each of the plurality of divided areas, the method comprising:

obtaining a positional information of the movable body, based on measurement results of a predetermined number of heads of the plurality of heads provided on the movable body which moves along a predetermined plane holding the object, by irradiating a measurement beam on a measurement plane having an opening in part of the measurement plane which is placed facing the movable body and roughly parallel to the predetermined plane, receiving a return beam from the measurement plane, and measuring a position of the movable body in each measurement direction;
stepping and driving the movable body toward a starting point of a constant speed drive to form the pattern in a divided area subject to formation of the plurality of divided areas, based on positional information obtained; and
switching at least one of the predetermined number of heads used to compute a positional information of the movable body according to a position of the movable body to a different head before the movable body is moved at a constant speed in the first direction to form the pattern in the divided area subject to formation, after the stepping and driving.

42. The exposure method according to Paragraph 41 wherein
after the switching, the movable body is moved at a constant speed in the first direction from the starting point to form the pattern in the divided area subject to formation.

43. The exposure method according to one of Paragraphs 41 and 42 wherein

an offset is made to reset a measurement result of a head to be used after the switching using the measurement results of the plurality of heads prior to the switching of the heads, and the measurement results of the heads are reset using the offset.

44. The exposure method according to Paragraph 43 wherein
when making the offset, measurement errors of the plurality of heads that occur due to acceleration of the movable body are corrected.

45. The exposure method according to one of Paragraphs 43 and 44 wherein
a redundant section is set in a path of the step and drive, and the offset is made while the movable body moves at a constant speed in the redundant section.

46. The exposure method according to any one of Paragraphs 43 to 45 wherein
the offset is made using a first positional information of the movable body which is obtained from measurement results of a first head group of the plurality of heads excluding heads that are used after the switching, and a second positional information of the movable body which is obtained from measurement results of a second head group of the plurality of heads including heads that are used after the switching.

47. The exposure method according to Paragraph 46 wherein
the offset is made by time averaging a difference of the first and second positional information.

48. The exposure method according to one of Paragraphs 46 and 47 wherein
the offset is made by collecting a difference of the first and second positional information for each predetermined time, and moving averaging the difference which has been collected.

49. The exposure method according to any one of Paragraphs 46 to 48 wherein
measurement results of the heads used after the switching are reset using the offset after the offset is converged.

50. The exposure method according to Paragraph 49 wherein
the measurement results of the heads used after the switching are reset when a difference of the first and the second positional information coincides with the offset which has been converged.

51. The exposure method according to any one of Paragraphs 46 to 50 wherein
measurement results of the heads used after the switching are reset so that each time average of the first and the second positional information coincides with each other.

52. The exposure method according to any one of Paragraphs 46 to 51 wherein
measurement results of the heads used after the switching are reset so that the first and second positional information of each predetermined time is collected, and a moving average of each of the first and second positional information which has been collected coincides with each other.

53. The exposure method according to any one of Paragraphs 46 to 52 wherein
measurement results of the heads used after the switching are reset while the movable body is moving at a constant speed.

54. The exposure method according to any one of Paragraphs 41 to 53 wherein
the constant speed movement in the first direction of the movable body is performed synchronously with a movement in the first direction of a different movable body holding a mask that is an original plate of the pattern.

55. The exposure method according to any one of Paragraphs 41 to 54 wherein
irradiation of the energy beam on the object is performed via an optical system.

56. An exposure method in which a plurality of divided areas placed in a shape of a matrix on an object is sequentially exposed by an energy beam, and a pattern is formed on each of the plurality of divided areas, the method comprising:

obtaining positional information of the movable body within a first area where of a plurality of heads provided on a movable body which moves along a predetermined plane holding the object, heads included in a first head group and a second head group which has at least one head different from the first head group face a meas-

urement plane which is provided roughly parallel to the predetermined plane, based on measurement results of the first head group, and performing a constant speed drive of the movable body in a first direction of the predetermined plane to form the pattern on a divided area subject to formation of the plurality of divided areas, based on the positional information; and
switching heads to be used to compute the positional information to the second heads group after the constant speed movement, before the movable body moves from the first area to a second area where heads included only in the second group face the measurement plane.

57. The exposure method according to Paragraph 56, the method further comprising:

making an offset to reset measurement results of the different head using measurement results of the first head group, and resetting the measurement results of the different head using the offset during the constant speed movement.

58. The exposure method according to one of Paragraphs 56 and 57, the method further comprising:

obtaining positional information of the movable body based on measurement results of the second head group after the switching, and based on the positional information which has been obtained, stepping and driving the movable body to a starting point of the constant speed movement to form the pattern in the next divided area subject to formation of the plurality of divided areas.

59. The exposure method according to any one of Paragraphs 56 to 58 wherein
the constant speed movement in the first direction of the movable body is performed synchronously with a movement in the first direction of another movable body holding a mask that is an original plate of the pattern.

60. The exposure method according to any one of Paragraphs 56 to 59 wherein
irradiation of the energy beam on the object is performed via an optical system.

61. An exposure method in which a plurality of divided areas placed in a shape of a matrix on an object is sequentially exposed by an energy beam, and a pattern is formed on each of the plurality of divided areas, the method comprising:

obtaining positional information of the movable body within a first area where of a plurality of heads provided on a movable body which moves along a predetermined plane holding the object, heads included in a first head group and a second head group which has at least one head different from the first head group face a measurement plane which is provided roughly parallel to the predetermined plane, based on measurement results of the first head group, and performing a step drive of the movable body toward a starting position of the constant speed movement to form the pattern on a divided area subject to formation of the plurality of divided areas, based on the positional information; and
switching heads to be used to measure the positional information to the second heads group after the step drive, before the movable body moves from the first area to the second area by being moved from the starting position in the first direction by the constant speed movement to form the pattern on a divided area subject to formation.

62. The exposure method according to Paragraph 61, the method further comprising:

making an offset to reset measurement results of the different head using measurement results of the first head group, and resetting the measurement results of the different head using the offset during the step drive.

63. The exposure method according to Paragraph 62 wherein
when making the offset, measurement errors of the plurality of heads that occur due to acceleration of the movable body are corrected.

64. The exposure method according to one of Paragraphs 62 and 63 wherein
a redundant section is set in a path of the step and drive, and
the offset is made while the movable body moves at a constant speed in the redundant section.

65. The exposure method according to any one of Paragraphs 62 to 64 wherein
the offset is made using a first positional information of the movable body obtained from measurement results of

the first head group and a second positional information of the movable body obtained from measurement results of the second head group.

66. The exposure method according to Paragraph 65 wherein
the offset is made by time averaging a difference of the first and second positional information.

67. The exposure method according to one of Paragraphs 65 and 66 wherein
the offset is made by collecting a difference of the first and second positional information for each predetermined time, and moving averaging the difference which has been collected.

68. The exposure method according to any one of Paragraphs 65 to 67 wherein
measurement results of the different head are reset using the offset after the offset is converged.

69. The exposure method according to Paragraph 68 wherein
the measurement results of the different head are reset when a difference of the first and the second positional information coincides with the offset which has been converged.

70. The exposure method according to any one of Paragraphs 65 to 69 wherein
measurement results of the different head are reset so that each time average of the first and the second positional information coincides with each other.

71. The exposure method according to any one of Paragraphs 65 to 70 wherein
measurement results of the different head is reset so that the first and second positional information of each predetermined time is collected, and a moving average of each of the first and second positional information which has been collected coincides with each other.

72. The exposure method according to any one of Paragraphs 65 to 71 wherein
measurement results of the different head are reset while the movable body is moving at a constant speed.

73. The exposure method according to any one of Paragraphs 61 to 72, the method further comprising:

obtaining positional information of the movable body based on measurement results of the second head group after the switching, and moving the movable body at a constant speed in the first direction from the starting point to form the pattern in the divided area subject to formation based on the positional information.

74. The exposure method according to any one of Paragraphs 61 to 73, the method further comprising:

the constant speed movement in the first direction of the movable body is performed synchronously with a movement in the first direction of a different movable body holding a mask that is an original plate of the pattern.

75. The exposure method according to any one of Paragraphs 61 to 74 wherein
irradiation of the energy beam on the object is performed via an optical system.

76. An exposure apparatus which sequentially exposes an energy beam on a plurality of divided areas placed in a shape of a matrix on an object, and forms a pattern on each of the plurality of divided areas, the apparatus comprising:

a movable body which holds the object and moves along a predetermined plane;
a position measurement system which has a plurality of heads provided on the movable body, and obtains positional information of the movable body based on measurement results of a predetermined number of heads of the plurality of heads which is obtained by irradiating a measurement beam on a measurement plane placed roughly parallel to the predetermined plane facing the movable body, receiving a return beam from the measurement plane, and measuring a position of the movable body in each measurement direction; and
a control system which drives the movable body based on positional information obtained from the position measurement system, as well as switch at least one head of the predetermined number of heads used to compute the positional information of the body at the time besides when a constant speed movement of the movable body is performed in a first direction within the predetermined plane to form the pattern in the divided area subject to formation of the plurality of divided areas to another head.

77. The exposure apparatus according to Paragraph 76 wherein
during the constant speed movement, an offset is made to reset measurement results of the another head using measurement results of the predetermined number of heads used to compute the positional information of the movable body before the switching, and the offset is used to reset the measurement results of the another head.

78. The exposure apparatus according to one of Paragraphs 76 and 77 wherein
based on the positional information of the movable body obtained from the measurement results of the predetermined number of heads after the switching, the movable body is stepped and driven to a starting point of the constant speed movement to form the pattern in the next divided area subject to formation of the plurality of divided areas.

79. The exposure apparatus according to any one of Paragraphs 76 to 78, the apparatus further comprising:

> a mask stage which holds a mask that is an original plate on which the pattern is formed, wherein
> the mask stage moves in the first direction synchronously with the constant speed movement of the movable body in the first direction.

80. The exposure apparatus according to any one of Paragraphs 76 to 79, the apparatus further comprising:

> an optical system which emits the energy beam to the object.

81. An exposure method in which a plurality of divided areas placed in a shape of a matrix on an object is sequentially exposed by an energy beam, and a pattern is formed on each of the plurality of divided areas, the method comprising:

> obtaining a positional information of the movable body, based on measurement results of a predetermined number of heads of the plurality of heads provided on the movable body which moves along a predetermined plane holding the object, by irradiating a measurement beam on a measurement plane having an opening in part of the measurement plane which is placed facing the movable body and roughly parallel to the predetermined plane, receiving a return beam from the measurement plane, and measuring a position of the movable body in each measurement direction; and
> switching at least one of the predetermined number of heads used to compute a positional information of the movable body according to a position of the movable body to a different head at a time besides when the movable body performs the constant speed movement in the first direction to form the pattern in the divided area subject to formation.

82. The exposure method according to Paragraph 81 wherein
an offset is made to reset a measurement result of a head to be used after the switching using the measurement results of the predetermined number of heads prior to the switching of the heads, and the measurement results of the heads are reset using the offset.

83. The exposure method according to one of Paragraphs 81 and 82 wherein
the constant speed movement in the first direction of the movable body is performed synchronously with a movement in the first direction of a different movable body holding a mask that is an original plate of the pattern.

84. The exposure method according to any one of Paragraphs 81 to 83 wherein
irradiation of the energy beam on the object is performed via an optical system.

85. A device manufacturing method, including
forming a pattern on an object using the exposure method according to any one of Paragraphs 36 to 75 and 81 to 84; and
developing the object on which the pattern is formed.

Claims

1. An exposure apparatus (100) for exposing a substrate (W) with illumination light (IL) via a projection optical system (PL), the apparatus comprising:

> a body having a metrology frame arranged for supporting the projection optical system;

an alignment system (ALG) provided to the metrology frame, spaced from the projection optical system, and configured to detect a mark of the substrate;
a first stage system having a first stage (RST) and a first drive system (11), and capable of moving the first stage at least within a predetermined plane (XY plane) orthogonal to an optical axis (AX) of the projection optical system, the first stage being disposed above the projection optical system and arranged for holding a mask (R) illuminated with the illumination light, and the first drive system including a first motor configured to drive the first stage;
a first encoder system configured to measure positional information of the first stage;
a second stage system having a second stage (WST1) and a second drive system (27), the second stage being disposed below the projection optical system and the alignment system and including a holder arranged for holding the substrate and a first fiducial and a second fiducial disposed with the holder in between in a direction intersecting a first direction and a second direction (Y-axis direction, X-axis direction) orthogonal to each other within the predetermined plane, and the second drive system including a second motor (30) configured to drive the second stage;
a second encoder system (70) that has four heads (60_1, to 60_4) provided to the second stage, and is configured to measure positional information of the second stage by irradiating a scale member (21, 22) from below with a measurement beam via each of the four heads, the scale member being provided to the metrology frame to be substantially parallel to the predetermined plane, wherein

> the scale member has a first scale plate (21) and a second scale plate (22), the second stage that is moved within a first movement area being placed facing the first scale plate in an exposure operation of the substrate, the second stage that is moved within a second movement area being placed facing the second scale plate in a detection operation of the mark with the alignment system, and the second movement area being different from the first movement area,
> the first scale plate has four sections (21_1 to 21_4) in each of which a reflection-type grating (RG) is formed, and a first opening (21a) that is substantially surrounded by the four sections, and the first scale plate is provided to the metrology frame so that the projection optical system is located in the first opening, and
> the second scale plate has four sections (22_1 to 22_4) in each of which a reflection-type grating (RG) is formed, and a second opening (22a) that is substantially surrounded by the four sections, and the second scale plate is provided to the metrology frame so that the alignment system is located in the second opening; and

a controller (20) coupled to the first and the second stage systems and the first and the second encoder systems, and configured to control the first and the second drive systems on the basis of measurement information of the first and the second encoder systems so that, in the exposure operation, alignment between the mask and the substrate is performed on the basis of detection information of the alignment system and scanning exposure in which the mask and the substrate are each moved relative to the illumination light is performed with the first direction serving as a scanning direction,
wherein the first movement area includes a first area (A_1), a second area (A_2), a third area (A_3), a fourth area (A_4) and a fifth area (A_0),

> in the first area (A_1), three heads (60_4, 60_1, 60_2) of the four heads excluding a first head (60_3) respectively facing three sections (21_4, 21_1, 21_2) of the four sections of the first scale plate excluding a first section (21_3),
> in the second area (A_2), three heads (60_1, 60_2, 60_3) of the four heads excluding a second head (60_4) different from the first head respectively facing three sections (21_1, 21_2, 21_3) of the four sections excluding a second section (21_4) different from the first section,
> in the third area (A_3), three heads (60_2, 60_3, 60_4) of the four heads excluding a third head (60_1) different from the first and the second heads respectively facing three sections (21_2, 21_3, 21_4) of the four sections excluding a third section (21_1) different from the first and the second sections,
> in the fourth area (A_4), three heads (60_1, 60_3, 60_4) of the four heads excluding a fourth head (60_2) different from the first, the second and the third heads respectively facing three sections (21_1, 21_3, 21_4) of the four sections excluding a fourth section (21_2) different from the first, the second and the third sections, and
> in the fifth area(A_0), the four heads respectively facing the four sections, and

wherein the controller is configured to control the second drive system so that marks of the substrate and the first fiducial are detected with the alignment system in the detection operation, and the second stage is moved from one area of the first, the second, the third and the fourth areas to another area of the first, the second, the third and the fourth areas, via the fifth area, the another area being different from the one area,

in the one area, three heads of the four heads respectively facing three sections of the four sections of the first scale plate,
in the fifth area, another head, of the four heads, that is different from the three heads used in the one area facing another section, of the four sections, that is different from the three sections, and
in the another area, the another head being used instead of one head of the three heads used in the one area.

2. The exposure apparatus according to Claim 1, wherein
the apparatus is configured such that, in the another area, three heads including two remaining heads and the another head face three sections including the another section and excluding one section to which the one head faces in the one area, of the four sections of the first scale plate, the remaining two heads excluding the one head of the three heads used in the one area.

3. The exposure apparatus according to Claim 2, wherein the apparatus is configured such that:

in a part of the another area, the one head does not face the one section to which the one head faces in the one area, of the four sections of the first scale plate; and
in a part of the one area, the another head does not face the another section to which the another head faces in the another area, of the four sections of the first scale plate.

4. The exposure apparatus according to any one of Claims 1 to 3, wherein
the controller is configured to switch the one head to the another head to be used in drive control of the second stage, when the second stage is moved from the one area to the another area via the fifth area.

5. The exposure apparatus according to Claim 4, wherein
the controller is configured to switch the one head to the another head while the second stage is in the fifth area.

6. The exposure apparatus according to any one of Claims 1 to 5, wherein
the controller is configured to acquire correction information for the positional information obtained from the another head used in the another area, on the basis of the positional information obtained from three heads used in the one area, when the second stage is moved from the one area to the another area via the fifth area.

7. The exposure apparatus according to Claim 6, wherein
the correction information includes an offset for compensating for a difference between the positional information obtained from the three heads used in the one area and the positional information obtained from the three heads including the another head that are used in the another area.

8. The exposure apparatus according to Claim 6 or 7, wherein
the apparatus is configured such that the correction information is used in a part of the exposure operation, in the part of the exposure operation the second stage being moved in the another area.

9. The exposure apparatus according to any one of Claims 6 to 8, wherein
the apparatus is configured such that the correction information is used to compensate for a measurement error of the second encoder system in the another area, the measurement error of the second encoder system occurring due to performing drive control of the second stage based on the positional information obtained from the three heads including the another head that are used in the another area, instead of drive control of the second stage based on the positional information obtained from the three heads used in the one area.

10. The exposure apparatus according to Claim 9, wherein
the controller is configured to switch the drive control of the second stage based on the positional information obtained from the three heads used in the one area to the drive control of the second stage based on the positional information obtained from the three heads including the another head that are used in the another area, while the four heads face the four sections of the first scale plate, respectively.

11. The exposure apparatus according to any one of Claims 6 to 10, wherein
the apparatus is configured such that the correction information is acquired while the second stage is in the fifth area.

12. The exposure apparatus according to any one of Claims 1 to 11, wherein
in each of the first and the second scale plates, the reflection-type grating is a two-dimensional grating, and each

of the first and the second scale plates is supported in a suspended manner by the metrology frame.

13. The exposure apparatus according to any one of Claims 1 to 12, wherein
the first and the second scale plates are provided so that the reflection-type gratings are substantially flush.

14. The exposure apparatus according to any one of Claims 1 to 13, wherein
in each of the first and the second scale plates, the four sections are each L-shaped, and the two-dimensional grating is periodic in two directions that are rotated at an angle of 45 degrees with respect to the first and the second directions within the predetermined plane.

15. The exposure apparatus according to any one of Claims 1 to 14, wherein
each of the first and the second scale plates has a non-effective area on an outer periphery of the four sections.

16. The exposure apparatus according to any one of Claims 1 to 15, wherein
the apparatus is configured such that the four heads are provided to the second stage so that a distance (B) between two heads (60_1, 60_4; 60_2, 60_3) of the four heads in the first direction is larger than each of a width (b_i) of the first opening and a width (b_i) of the second opening in the first direction, and a distance (A) between two heads (60_1, 60_2; 60_3, 60_4) of the four heads in the second direction is larger than each of a width (a_i) of the first opening and a width (a_i) of the second opening in the second direction.

17. The exposure apparatus according to any one of Claims 1 to 16, wherein
the apparatus is configured such that:

the second encoder system is capable of measuring positional information of the second stage in directions of six degrees of freedom, the directions of six degrees of freedom including the first and the second directions and a third direction orthogonal to the predetermined plane; and
each of the four heads is capable of measuring positional information of the second stage in two directions, the two directions being a direction parallel to the predetermined plane and a direction perpendicular to the predetermined plane.

18. The exposure apparatus according to any one of Claims 1 to 17, wherein
the second encoder system has at least one head that is different from the four heads and is disposed in proximity to each of the four heads.

19. The exposure apparatus according to any one of Claims 1 to 18, wherein
the controller is configured to control movement of the second stage while compensating for a measurement error of the second encoder system that occurs due to at least one of a production error of the first and the second scale plates, acceleration of the second stage and a position or tilt of the head.

20. The exposure apparatus according to any one of Claims 1 to 19, wherein
the body has a base member (12) to which the second stage is disposed,
the second stage system has another second stage (WST2) that is different from the second stage and is disposed on the base member, and
the second encoder system has four heads provided to the another second stage and different from the four heads provided to the second stage, and is configured to measure positional information of the another second stage with at least three of the four heads provided to the another second stage.

21. The exposure apparatus according to Claim 20, wherein
the second motor includes a planar motor (30) of a magnetic levitation type that levitates and supports the two second stages on the base member, and the apparatus is configured such that each of the two second stages is moved from the second movement area to the first movement area by the planar motor so that the exposure operation is performed following the detection operation.

22. The exposure apparatus according to Claim 21, wherein
the planar motor has a magnet unit provided to one of the base member and the two second stages and a coil unit provided to the other of the base member and the two second stages, and
the apparatus is configured such that the base member is used as a counter mass that is conf igured movable by a reaction force generated by movement of the two second stages.

23. A device manufacturing method, comprising:

exposing a wafer using the exposure apparatus according to any one of Claims 1 to 22; and
developing the wafer that has been exposed.

24. The device manufacturing method according to Claim 23, wherein
the exposure apparatus is a liquid immersion type exposure apparatus.

25. An exposure method of exposing a substrate with illumination light via a projection optical system, the method comprising:

holding a mask illuminated with the illumination light, with a first stage disposed above the projection optical system, the first stage being movable at least within a predetermined plane orthogonal to an optical axis of the projection optical system;
holding the substrate with a second stage disposed below the projection optical system and an alignment system that is provided to a metrology frame, spaced from the projection optical system, and detects a mark of the substrate, the second stage having a holder to hold the substrate and a first fiducial and a second fiducial that are disposed with the holder in between in a direction intersecting a first direction and a second direction orthogonal to each other within the predetermined plane, and the metrology frame supporting the projection optical system;
measuring positional information of the first stage and positional information of the second stage with a first encoder system and a second encoder system, respectively, the second encoder system having four heads provided to the second stage, and irradiating a scale member from below with a measurement beam via each of the four heads, and the scale member being provided to the metrology frame to be substantially parallel to the predetermined plane, wherein

the scale member has a first scale plate and a second scale plate, the second stage that is moved within a first movement area being placed facing the first scale plate in an exposure operation of the substrate, the second stage that is moved within a second movement area being placed facing the second scale plate in a detection operation of the mark with the alignment system, and the second movement area being different from the first movement area,
the first scale plate has four sections in each of which a reflection-type grating is formed, and a first opening that is substantially surrounded by the four sections, and the first scale plate is provided to the metrology frame so that the projection optical system is located in the first opening, and
the second scale plate has four sections in each of which a reflection-type grating is formed, and a second opening that is substantially surrounded by the four sections, and the second scale plate is provided to the metrology frame so that the alignment system is located in the second opening;

moving the second stage within the second movement area so that marks of the substrate and the first fiducial are detected with the alignment system, in the detection operation; and
moving the first and the second stages within the first movement area on the basis of measurement information of the first and the second encoder systems so that, in the exposure operation, alignment between the mask and the substrate is performed on the basis of detection information of the alignment system and scanning exposure in which the mask and the substrate are each moved relative to the illumination light is performed with the first direction serving as a scanning direction,
wherein the first movement area includes a first area, a second area, a third area, a fourth area and a fifth area,

in the first area, three heads of the four heads excluding a first head respectively facing three sections of the four sections of the first scale plate excluding a first section,
in the second area, three heads of the four heads excluding a second head different from the first head respectively facing three sections of the four sections excluding a second section different from the first section,
in the third area, three heads of the four heads excluding a third head different from the first and the second heads respectively facing three sections of the four sections excluding a third section different from the first and the second sections,
in the fourth area, three heads of the four heads excluding a fourth head different from the first, the second and the third heads respectively facing three sections of the four sections excluding a fourth section different from the first, the second and the third sections, and

in the fifth area, the four heads respectively facing the four sections, and

wherein, in the exposure operation, the second stage is moved from one area of the first, the second, the third and the fourth areas to another area of the first, the second, the third and the fourth areas, via the fifth area, the another area being different from the one area,

in the one area, three heads of the four heads respectively facing three sections of the four sections of the first scale plate,
in the fifth area, another head, of the four heads, that is different from the three heads used in the one area facing another section, of the four sections, that is different from the three sections, and
in the another area, the another head being used instead of one head of the three heads used in the one area.

26. The exposure method according to Claim 25, wherein
in the another area, three heads including two remaining heads and the another head face three sections including the another section and excluding one section to which the one head faces in the one area, of the four sections of the first scale plate, the remaining two heads excluding the one head of the three heads used in the one area.

27. The exposure method according to Claim 26, wherein
in a part of the another area, the one head does not face the one section to which the one head faces in the one area, of the four sections of the first scale plate, and
in a part of the one area, the another head does not face the another section to which the another head faces in the another area, of the four sections of the first scale plate.

28. The exposure method according to any one of Claims 25 to 27, wherein
the one head is switched to the another head to be used in drive control of the second stage, when the second stage is moved from the one area to the another area via the fifth area.

29. The exposure method according to Claim 28, wherein
the one head is switched to the another head while the second stage is in the fifth area.

30. The exposure method according to any one of Claims 25 to 29, wherein
correction information for the positional information obtained from the another head used in the another area is acquired, on the basis of the positional information obtained from three heads used in the one area, when the second stage is moved from the one area to the another area via the fifth area.

31. The exposure method according to Claim 30, wherein
the correction information includes an offset for compensating for a difference between the positional information obtained from the three heads used in the one area and the positional information obtained from the three heads including the another head that are used in the another area.

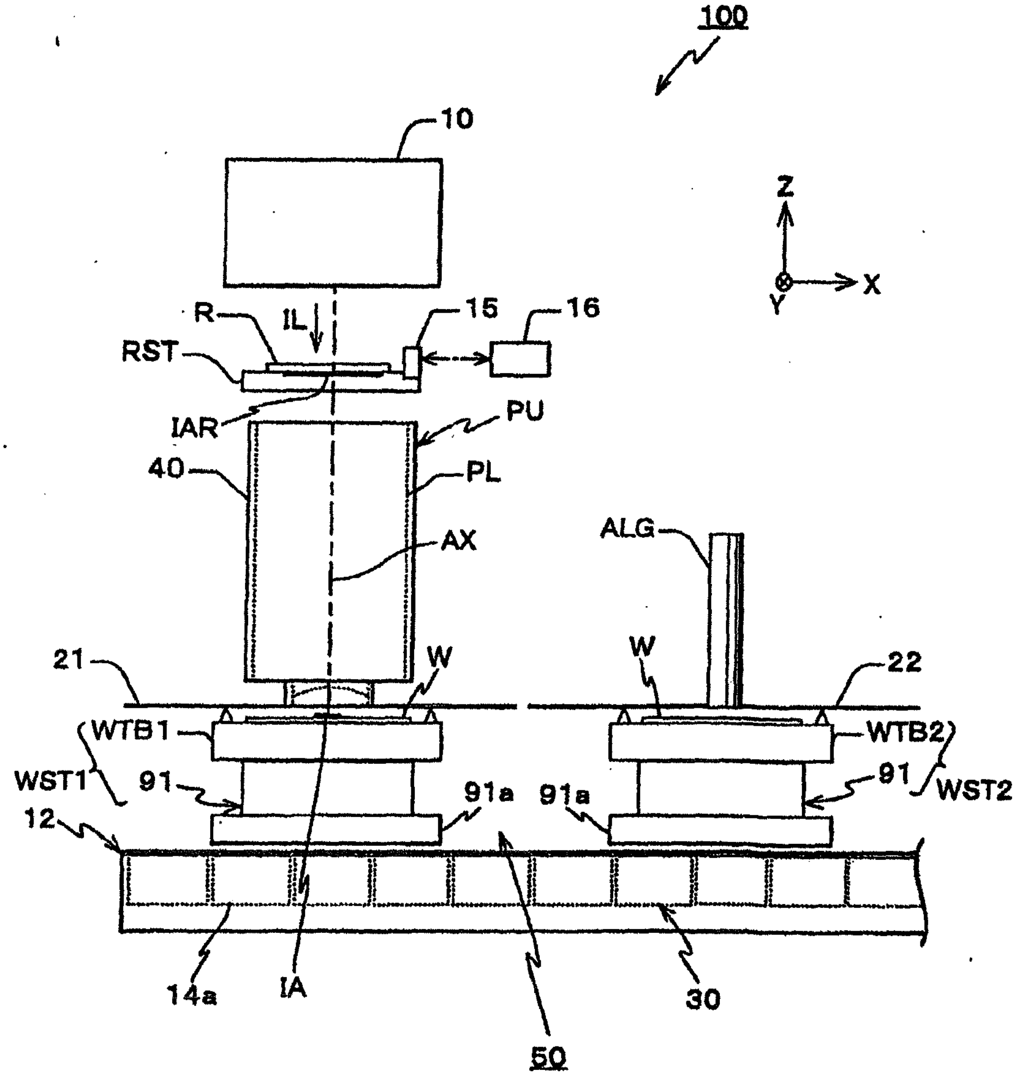
32. The exposure method according to Claim 30 or 31, wherein
the correction information is used in a part of the exposure operation, in the part of the exposure operation the second stage being moved in the another area.

33. The exposure method according to any one of Claims 30 to 32, wherein
the correction information is acquired while the second stage is in the fifth area.

34. A device manufacturing method, comprising:

exposing a wafer using the exposure method according to any one of Claims 25 to 33; and
developing the wafer that has been exposed.

Fig. 1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RST
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PU
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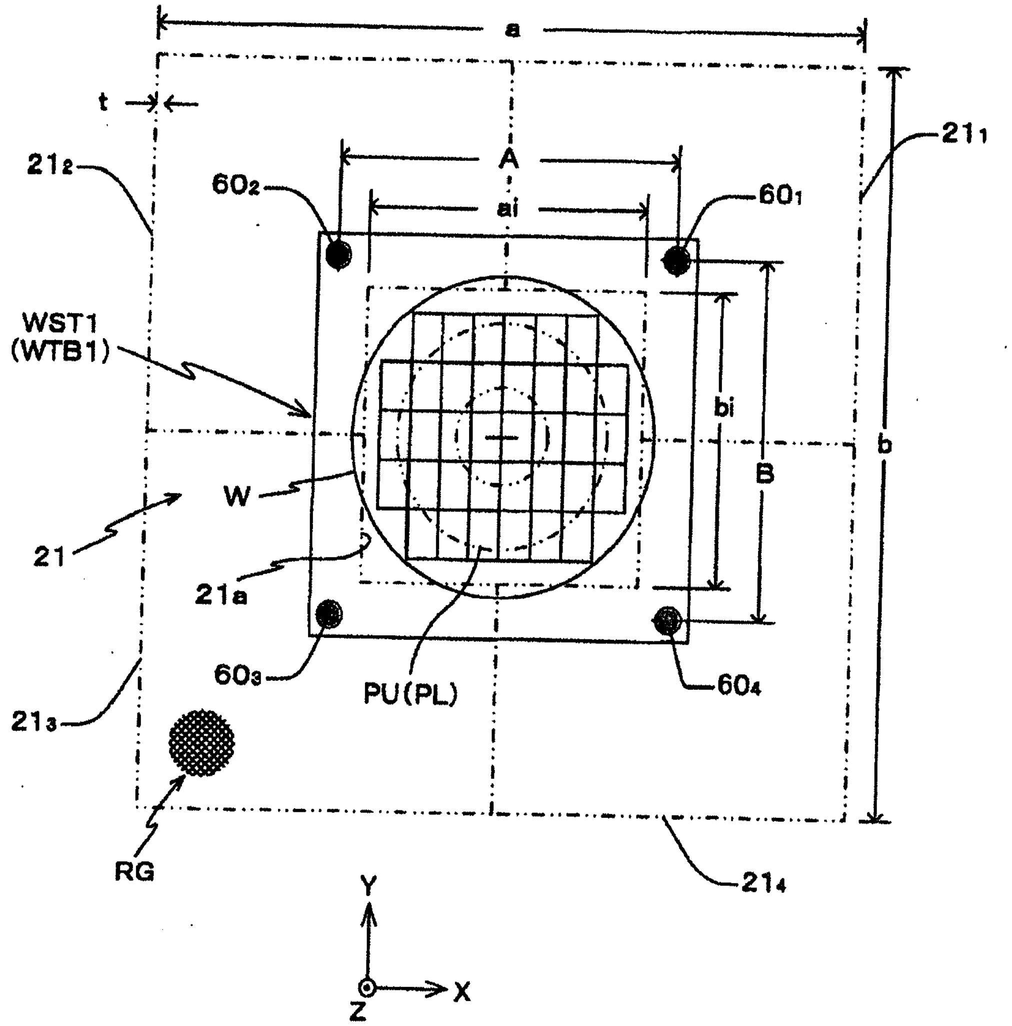
W
W
22
WTB1
WTB2
WST1
91
91
WST2
91a
91a
12
14a
IA
30
50

Fig. 2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PU(PL)
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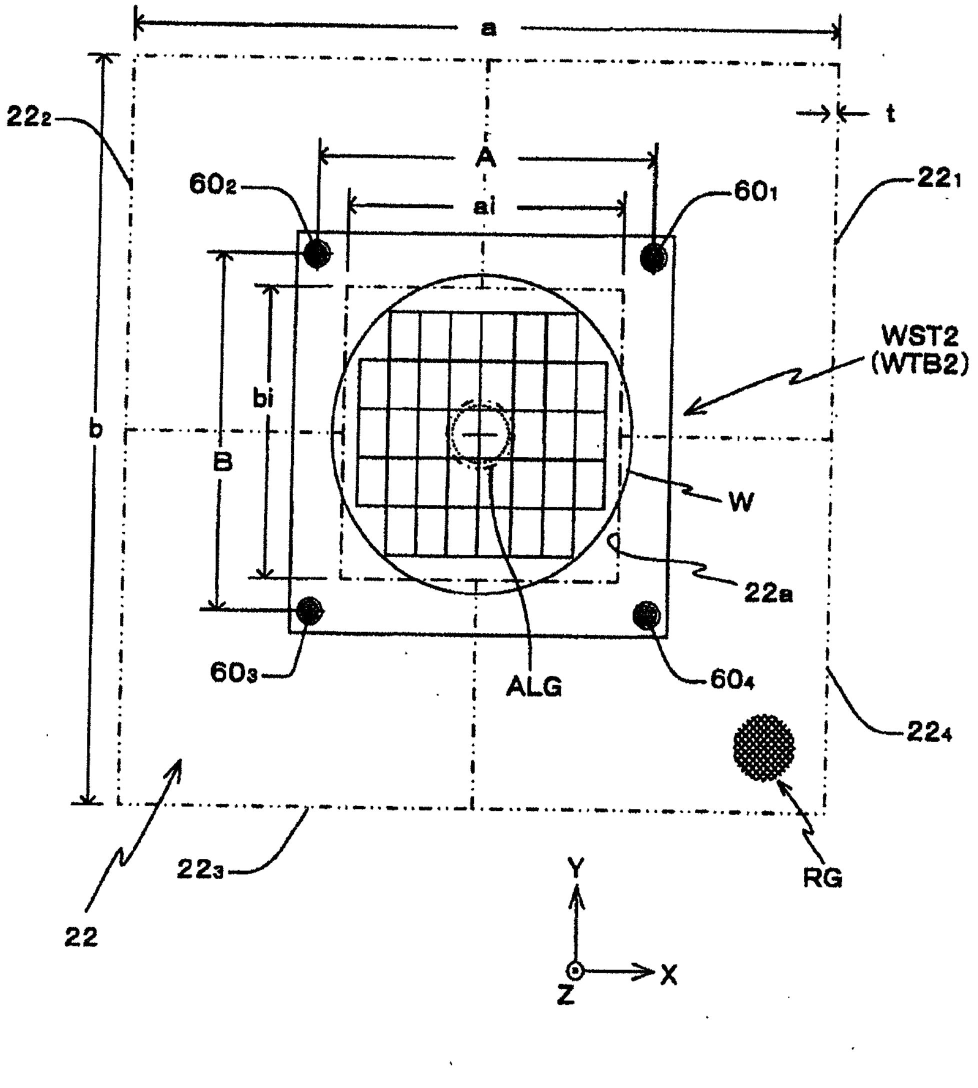
RG
21₄
Y
X
Z

Fig. 3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22
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X
Z

Fig. 4

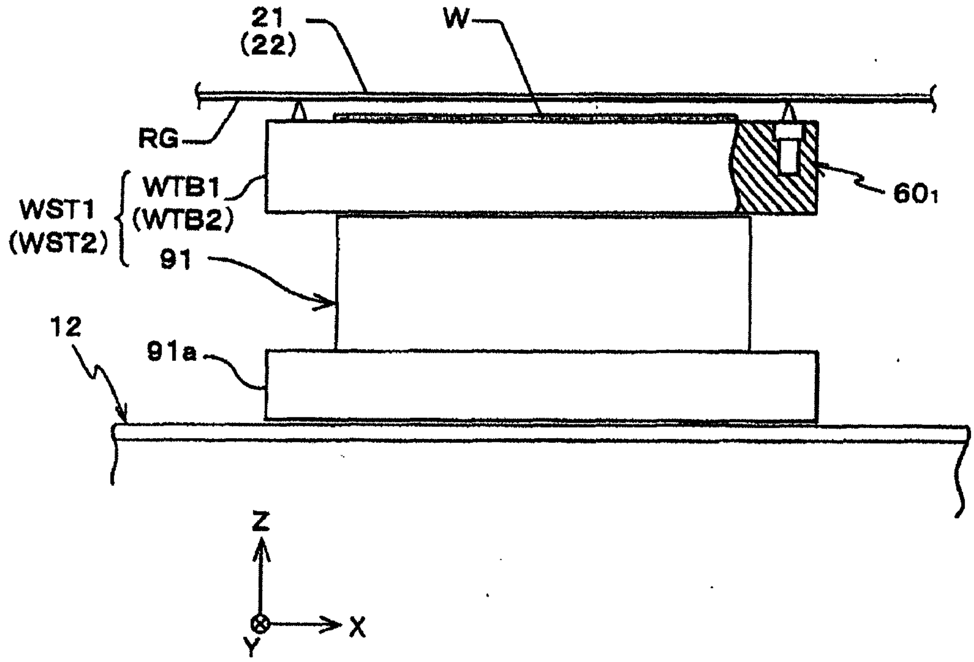
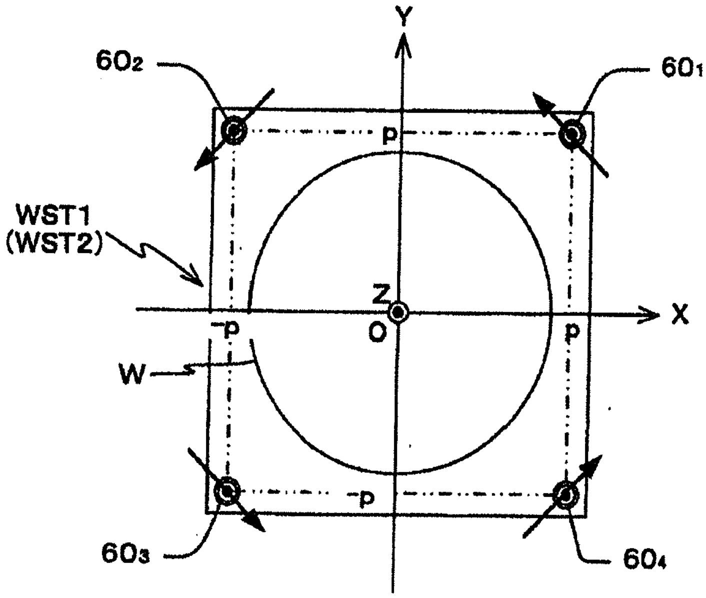


Fig. 5



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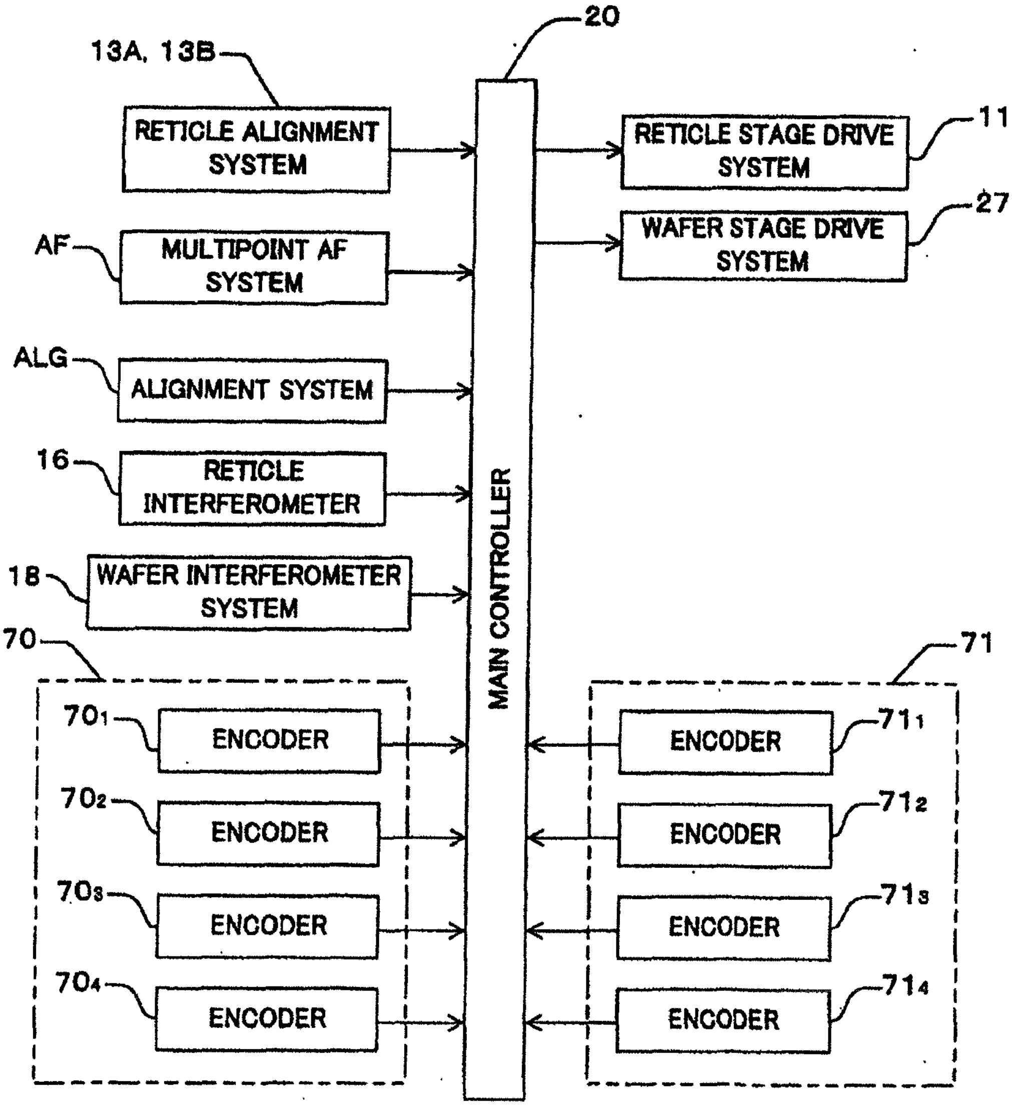
20
13A, 13B
RETICLE ALIGNMENT SYSTEM
RETICLE STAGE DRIVE SYSTEM
11
WAFER STAGE DRIVE SYSTEM
27
AF
MULTIPOINT AF SYSTEM
ALG
ALIGNMENT SYSTEM
16
RETICLE INTERFEROMETER
18
WAFER INTERFEROMETER SYSTEM
MAIN CONTROLLER
70
71
70₁
ENCODER
70₂
ENCODER
70₃
ENCODER
70₄
ENCODER
71₁
ENCODER
71₂
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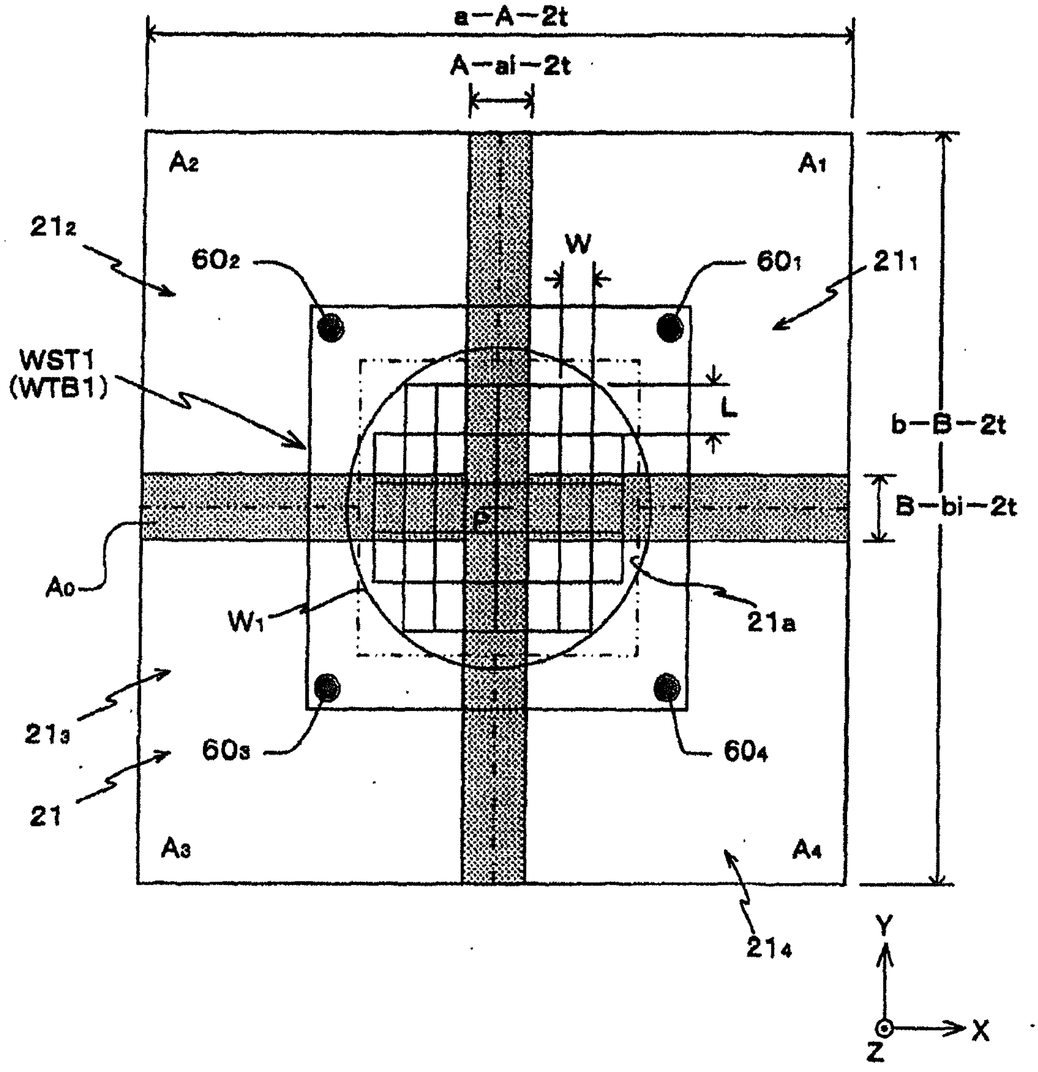
71₃
ENCODER
71₄
ENCODER

Fig. 7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(WTB1)
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P
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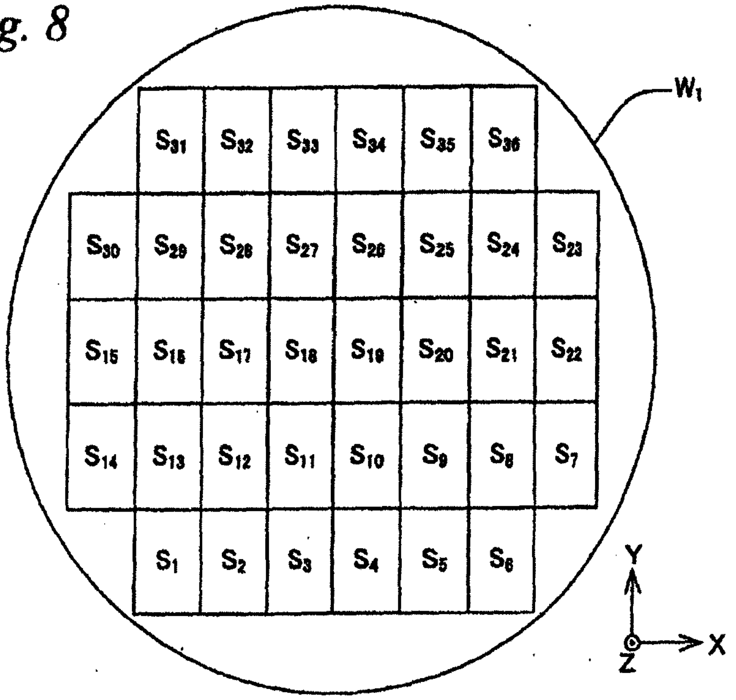
21a
213
603
604
21
A3
A4
214
Y
X
Z

Fig. 8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S30
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S16
S17
S18
S19
S20
S21
S22
S14
S13
S12
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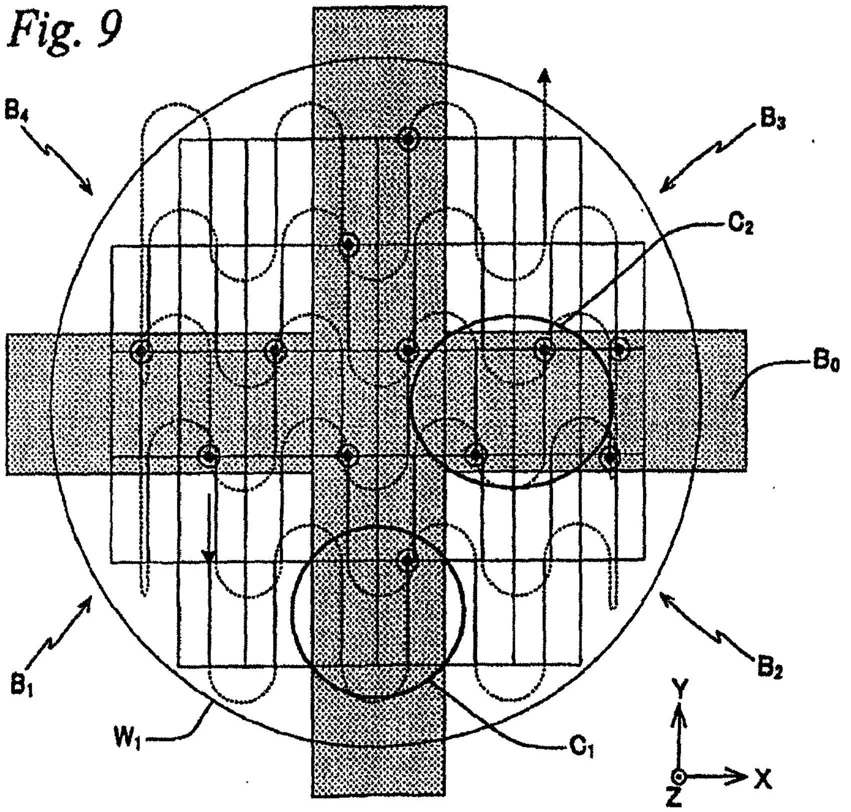
S8
S7
S1
S2
S3
S4
S5
S6
Y
X
Z

Fig. 9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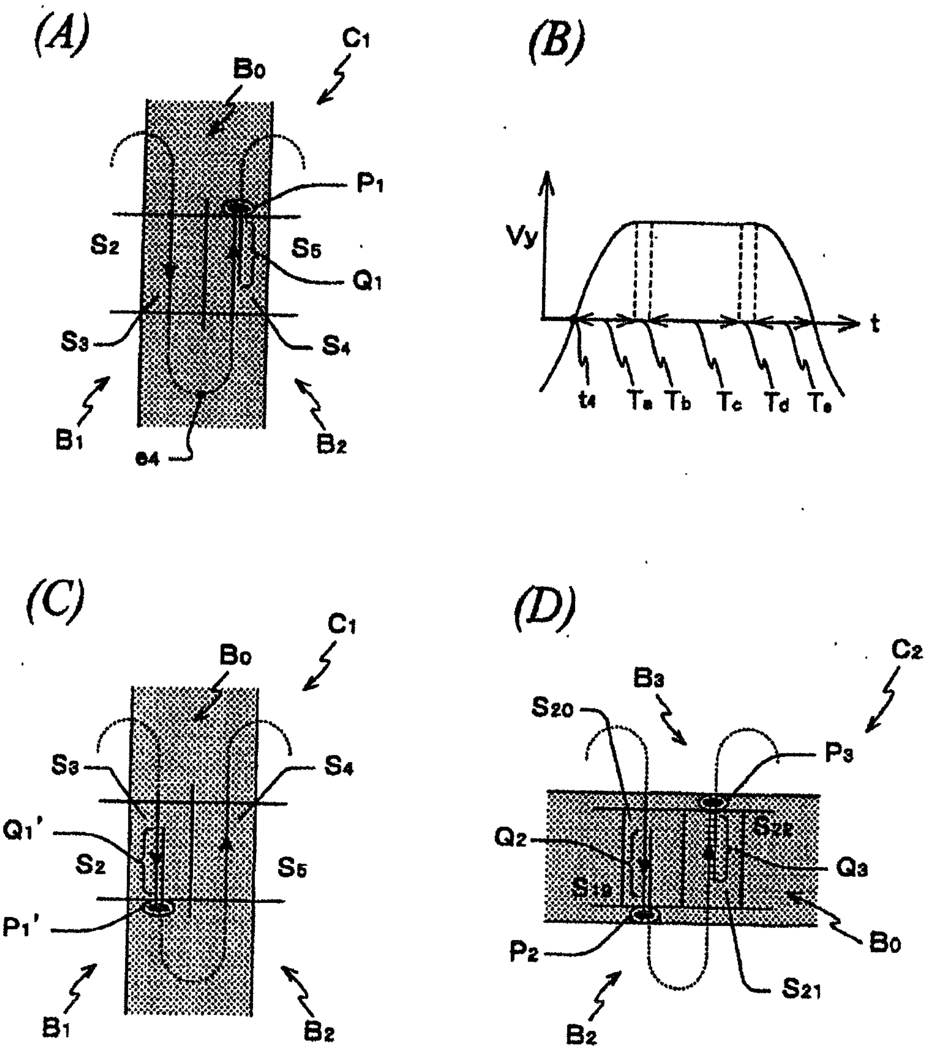
B1
B2
W1
C1
Y
X
Z

Fig. 10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B0
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S2
S5
Q1
S3
S4
B1
e4
B2
(B)
Vy
t
t4
Ta
Tb
Tc
Td
Te
(C)
C1
B0
S3
S4
Q1'
S2
S5
P1'
B1
B2
(D)
C2
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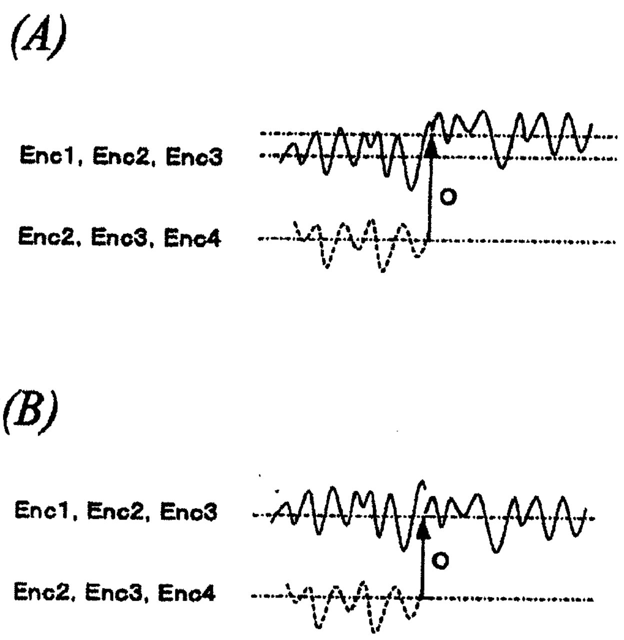
S20
P3
Q2
S22
Q3
S19
B0
P2
S21
B2

Fig. 11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Enc2, Enc3, Enc4
(B)
Enc1, Enc2, Enc3
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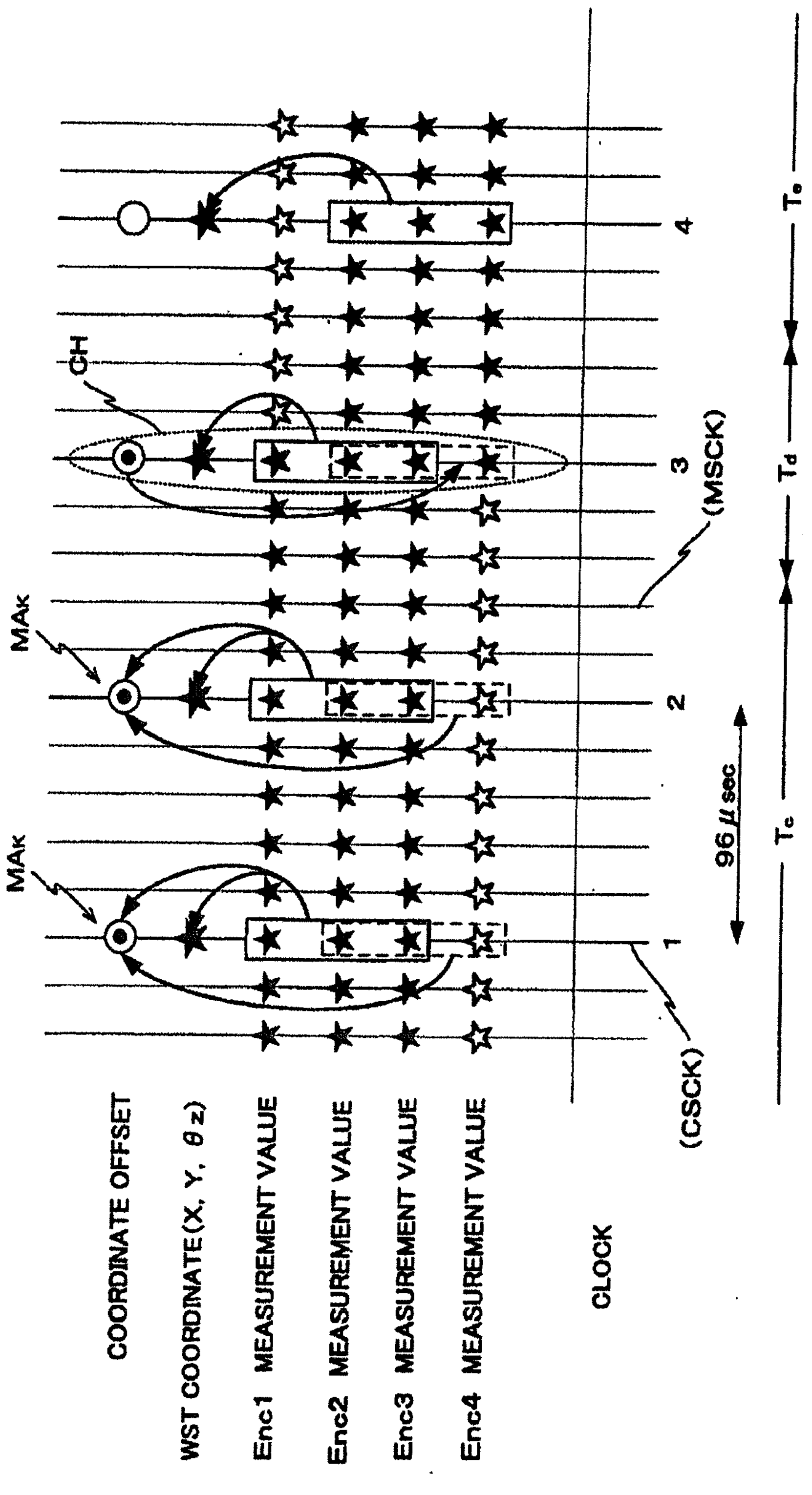
Enc2, Enc3, Enc4

Fig. 12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WST COORDINATE (X, Y, θz)
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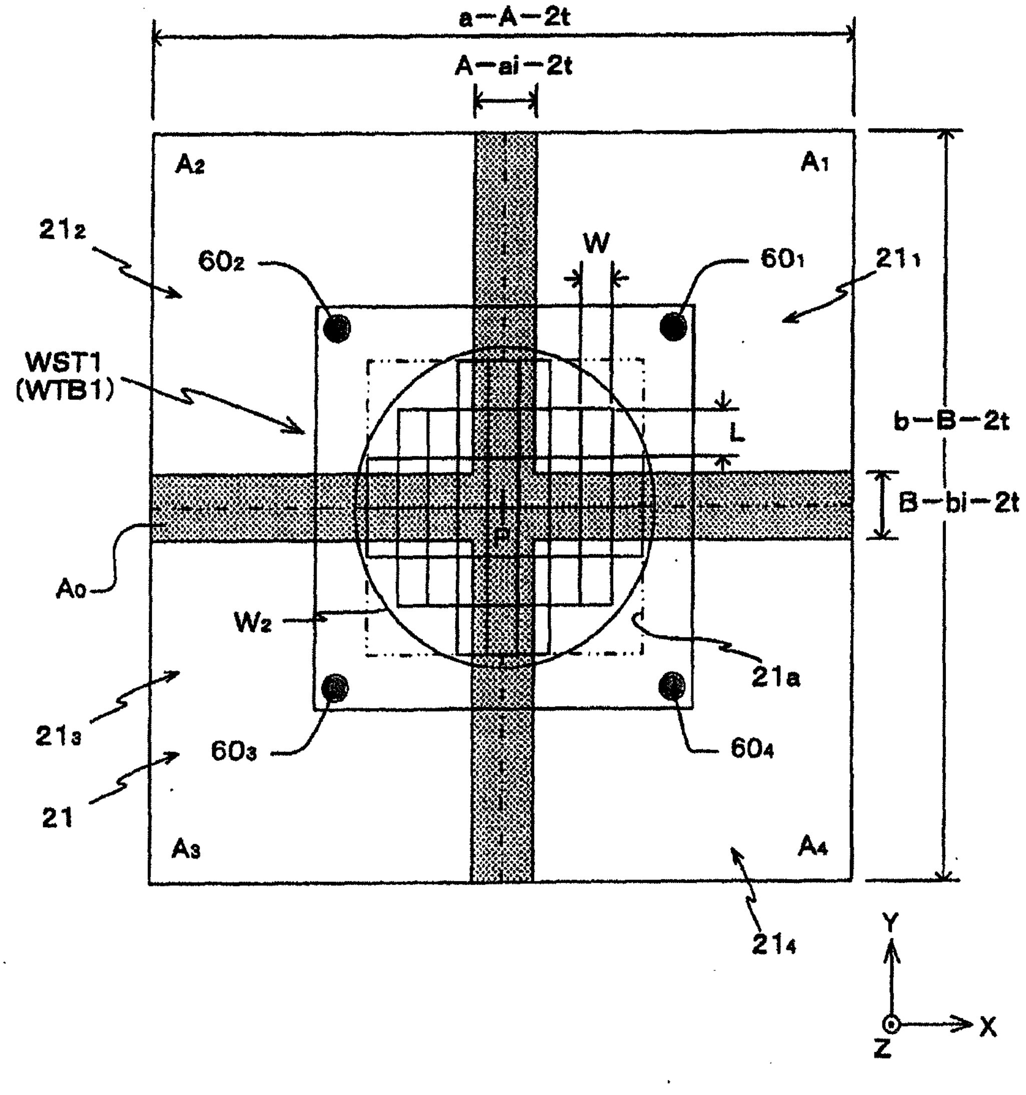
Enc2 MEASUREMENT VALUE
Enc3 MEASUREMENT VALUE
Enc4 MEASUREMENT VALUE
CLOCK
(CSCK)
MAK
MAK
CH
1
2
3
(MSCK)
4
96 μsec
Tc
Td
Te

Fig. 13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X
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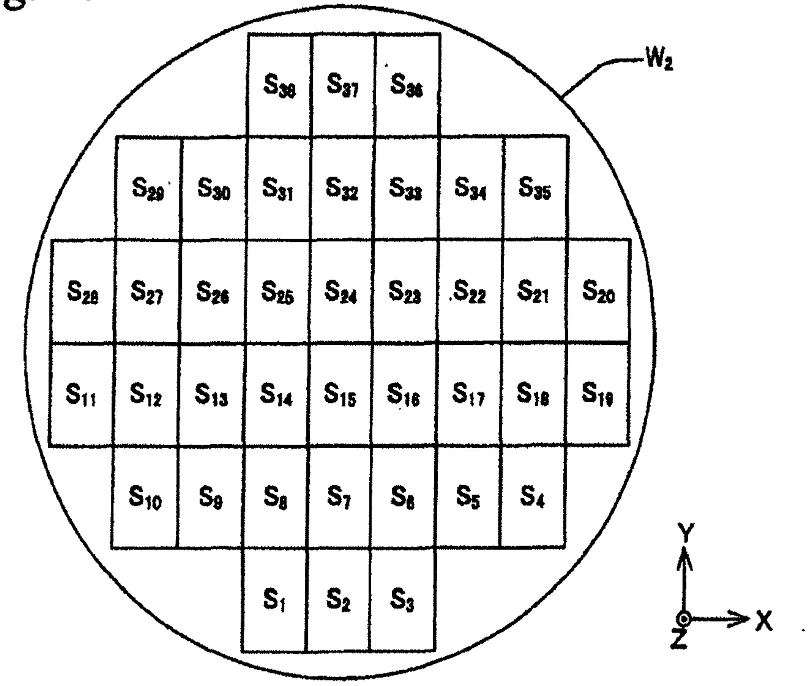
Fig. 14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S_{10}
S_9
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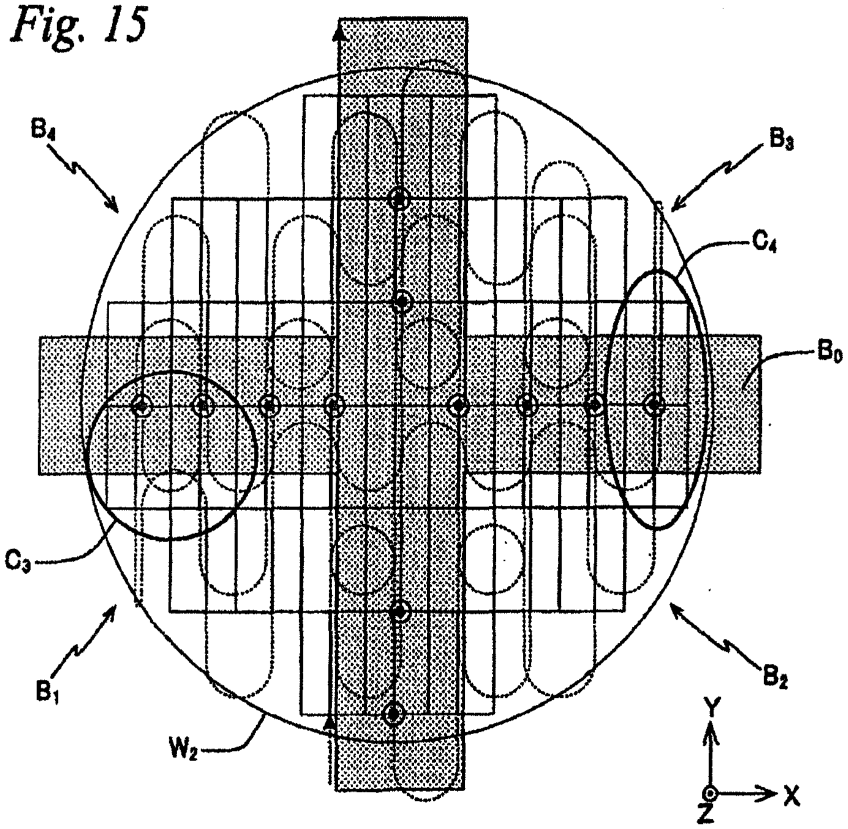
S_3
W_2
Y
X
Z

Fig. 15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C_4
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W_2
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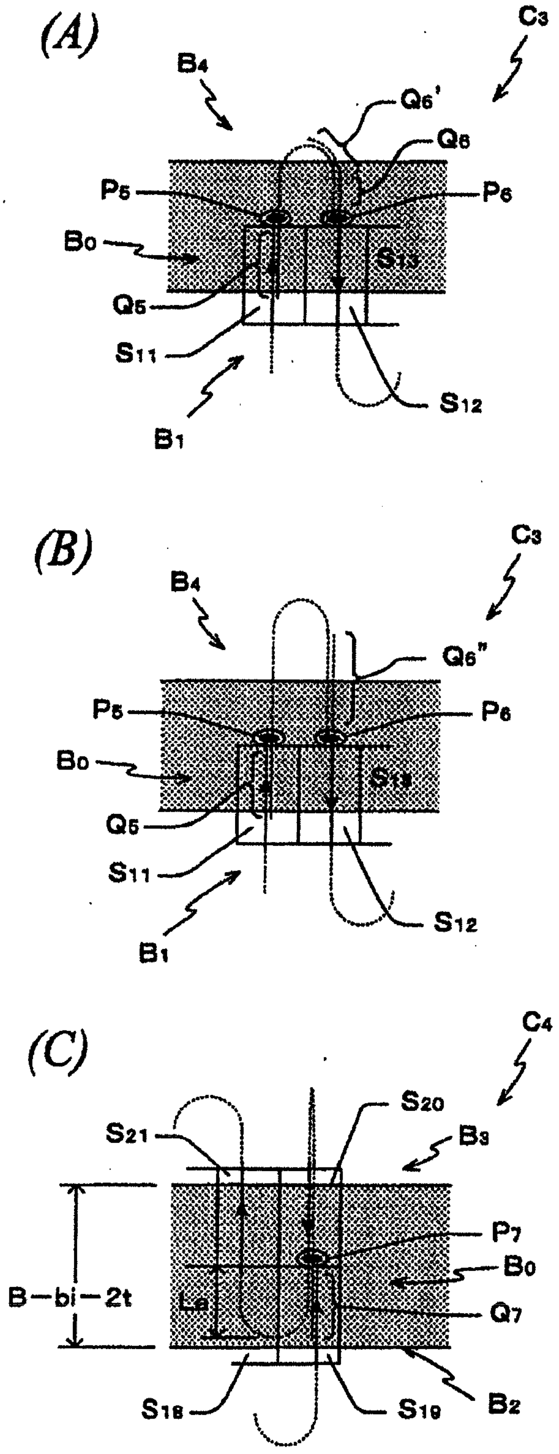
X
Z

Fig. 16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B4
Q6"
P5
P6
B0
S13
Q5
S11
S12
B1
(C)
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S19
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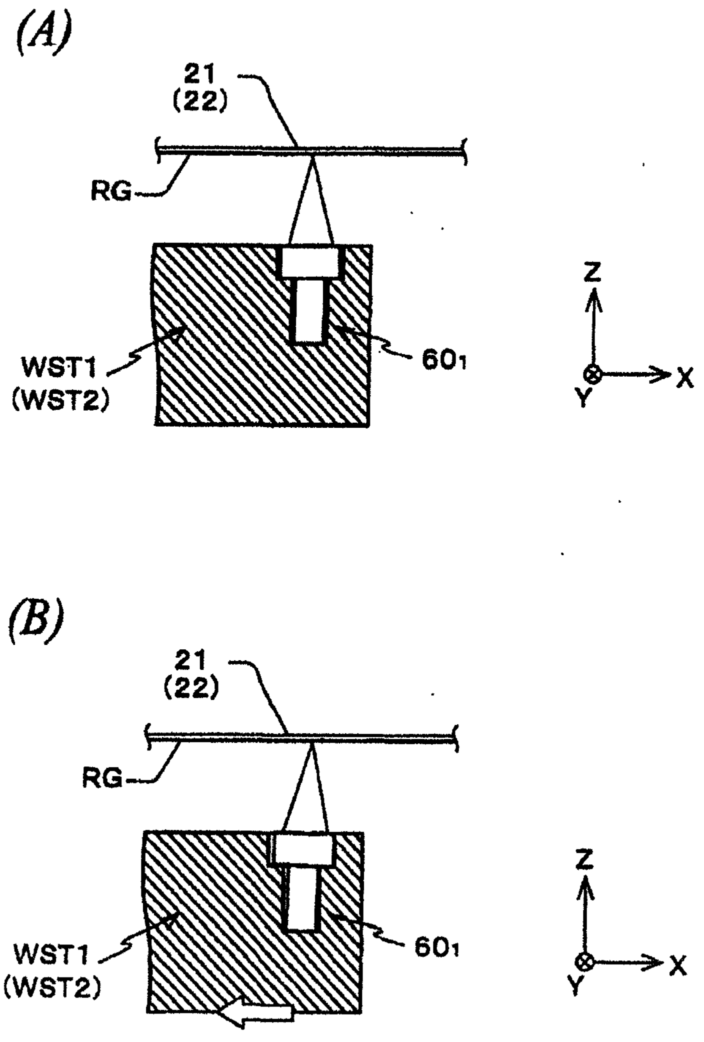
Fig. 17



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EUROPEAN SEARCH REPORT

Application Number
EP 18 15 8079

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2009/128791 A1 (KOENEN WILLEM HERMAN GERTRUDA ANNA [NL] ET AL) 21 May 2009 (2009-05-21) * paragraphs [0030] - [0049]; figures 1,2A * -----	1,25	INV. G03F7/20 G01B11/27 G03F9/00
A	US 7 253 875 B1 (LUTTIKHUIS BERNARDUS ANTONIUS [NL] ET AL) 7 August 2007 (2007-08-07) * column 5, line 52 - column 6, line 34; figure 2a * * column 8, line 50 - column 9, line 32; figure 4 * -----	1-34	
A	US 2009/153822 A1 (SHIBAZAKI YUICHI [JP]) 18 June 2009 (2009-06-18) * paragraph [0056] - paragraph [0063]; figures 1,2A-B,3A-B * * paragraph [0100] - paragraph [0112]; figure 5 * -----	1,25	
			TECHNICAL FIELDS SEARCHED (IPC)
A	JP 2007 318119 A (ASML NETHERLANDS BV) 6 December 2007 (2007-12-06) * abstract * -& US 2007/263197 A1 (LUTTIKHUIS BERNARDUS ANTONIUS [NL] ET AL) 15 November 2007 (2007-11-15) * paragraph [0038] - paragraph [0065]; figures 2,3a-d * -----	1-34	G03F H01L
A	EP 1 826 615 A2 (ASML NETHERLANDS BV [NL]) 29 August 2007 (2007-08-29) * paragraph [0040] - paragraph [0050]; figure 2 * ----- -/--	1-34	

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	4 June 2018	van Toledo, Wiebo

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EUROPEAN SEARCH REPORT

Application Number
EP 18 15 8079

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A,D	US 2006/227309 A1 (LOOPSTRA ERIK R [NL] ET AL LOOPSTRA ERIK ROELOF [NL] ET AL) 12 October 2006 (2006-10-12) * paragraphs [0046] - [0056]; figure 2 * * paragraph [0081] * -----	1-17	
A	US 2008/319569 A1 (LOOPSTRA ERIK ROELOF [NL] ET AL) 25 December 2008 (2008-12-25) * paragraph [0066] - paragraph [0087]; figures 2-4 * -----	1,25	
			TECHNICAL FIELDS SEARCHED (IPC)

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	4 June 2018	van Toledo, Wiebo

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X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
....
& : member of the same patent family, corresponding document

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 18 15 8079

04-06-2018

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2009128791 A1	21-05-2009	CN 101487979 A	22-07-2009
		JP 5036914 B2	26-09-2012
		JP 2009135490 A	18-06-2009
		JP 2012124534 A	28-06-2012
		KR 20090052296 A	25-05-2009
		TW 200928621 A	01-07-2009
		US 2009128791 A1	21-05-2009
US 7253875 B1	07-08-2007	CN 101030042 A	05-09-2007
		JP 4621700 B2	26-01-2011
		JP 2007251156 A	27-09-2007
		KR 20070090804 A	06-09-2007
		TW 200734835 A	16-09-2007
		US 7253875 B1	07-08-2007
US 2009153822 A1	18-06-2009	CN 101681121 A	24-03-2010
		HK 1136878 A1	08-03-2013
		JP 5169786 B2	27-03-2013
		JP 2009147342 A	02-07-2009
		KR 20100101068 A	16-09-2010
		SG 185938 A1	28-12-2012
		TW 200942977 A	16-10-2009
		US 2009153822 A1	18-06-2009
		WO 2009078473 A1	25-06-2009
JP 2007318119 A	06-12-2007	CN 101071276 A	14-11-2007
		JP 4660503 B2	30-03-2011
		JP 2007318119 A	06-12-2007
		KR 20070109871 A	15-11-2007
		TW 200801859 A	01-01-2008
		US 2007263197 A1	15-11-2007
US 2007263197 A1	15-11-2007	CN 101071276 A	14-11-2007
		JP 4660503 B2	30-03-2011
		JP 2007318119 A	06-12-2007
		KR 20070109871 A	15-11-2007
		TW 200801859 A	01-01-2008
		US 2007263197 A1	15-11-2007
EP 1826615 A2	29-08-2007	CN 101055425 A	17-10-2007
		EP 1826615 A2	29-08-2007
		JP 4486976 B2	23-06-2010
		JP 2007266581 A	11-10-2007
		KR 20070085158 A	27-08-2007
		SG 135129 A1	28-09-2007
		TW 200745770 A	16-12-2007

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
		US 2007195296 A1	23-08-2007
US 2006227309 A1	12-10-2006	CN 1932650 A	21-03-2007
		EP 1762897 A1	14-03-2007
		JP 4452262 B2	21-04-2010
		JP 2007129194 A	24-05-2007
		SG 131056 A1	26-04-2007
		TW 200712794 A	01-04-2007
		US 2006227309 A1	12-10-2006
US 2008319569 A1	25-12-2008	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- US 20060227309 A **[0006]**
- US 20030025890 A **[0030]**
- US 20070288121 A **[0032]**
- US 20080068568 A **[0034]**
- US 7561280 B **[0047]**
- US 20020041377 A **[0050]**
- US 20080088843 A **[0056]**
- US 5448332 A **[0057]**
- US 5646413 A **[0058] [0061]**
- US 4780617 A **[0060]**
- US 20080094592 A **[0075] [0092]**
- US 6590634 B **[0163]**
- US 5969441 A **[0163]**
- US 6208407 B **[0163]**
- US 20070211235 A **[0163]**
- US 20070127006 A **[0163]**
- US 9949504 W **[0164]**
- US 20050259234 A **[0164]**
- US 7023610 B **[0166]**
- US 6778257 B **[0167]**
- US 2001035168 W **[0168]**
- US 6611316 B **[0169]**

摘要

本发明涉及曝光装置、曝光方法、以及组件制造方法。本发明的曝光装置，具备在涵盖除了投影光学系统(PL)正下方区域外的晶圆载台(WST1)移动范围的标尺板(21)上，使用晶圆载台(WST1)上搭载的四个读头(601～604)照射测量光束据以测量晶圆载台(WST1)的位置信息的编码器系统。此处，读头(601～604)的配置间隔(A、B)系设定为分别大于标尺板(21)的开口的宽度(a、b)。如此，视晶圆载台的位置从四个读头中切换并使用与标尺板对向的三个读头，即能测量晶圆载台的位置信息。