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DESCRIPTION

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REFERENCE WAFER FOR ACCURACY CONTROL, MANUFACTURING METHOD OF THE SAME, EXPOSURE APPARATUS AND DEVICE MANUFACTURING METHOD

TECHNICAL FIELD

The present invention relates to a reference wafer for accuracy control, its manufacturing method, and an exposure apparatus and a device manufacturing method. More particularly, the present invention relates to a reference wafer for accuracy control, which is used for accuracy control of an exposure apparatus used in a lithography process for manufacturing a semiconductor device (an integrated circuit), a liquid crystal display device and the like, its manufacturing method, and an exposure apparatus in which accuracy is controlled by using the reference wafer for the accuracy control, and a device manufacturing method, in which an electronic device is manufactured by using the exposure apparatus.

BACKGROUND ART

Conventionally, in a lithography process where an electronic device such as a semiconductor device (an integrated circuit) and a liquid crystal display device (a display) is manufactured, various exposure apparatuses for forming a fine pattern on a substrate of an electronic device have been used. In recent years, a reduction projection exposure apparatus of a serial moving type such as a so-called stepper or a so-called

scanning stepper is mainly used, where a photomask (also referred to as a reticle) on which a pattern to be formed on the substrate is proportionally magnified by about four to five times and formed, is used, and where the pattern of the photomask is reduced and transferred onto a substrate (a substrate to be exposed) such as a wafer or a glass plate via a projection optical system .

In manufacturing the electronic device, a few tens of layers of circuit patterns need to be overlaid on the substrate, and exposure of the fine patterns is repeated for a few tens of times. In this case, to normally operate the electronic device as a complete product, it is required that a positional relation between the patterns of each layer is in a desired positional relation, specifically, that the reticle and patterns already formed on the wafer are overlaid with good accuracy. For this reason, an alignment mechanism for accurately coinciding the positional relation of the pattern on the reticle and the patterns on the wafer with each other is built in the projection exposure apparatus. However, there has been the case where fluctuation (a positional shift) occurred due to a temperature change, the atmospheric pressure change and the like in a factory.

To prevent this positional shift, a reference wafer for accuracy control is made in advance, on which a mark for alignment (an alignment mark) and a mark pattern (a reference pattern) used as a mark for measuring the positional shift are formed. With the use of the reference wafer, accuracy control of the projection exposure apparatus is performed. Specifically, a

resist is coated on the reference wafer, the pattern on the reticle (a mark pattern corresponding to the reference pattern (hereinafter, referred to as a "reticle mark")) is superimposed and transferred, and the positional relation between a resist image of the reticle mark formed on the wafer and the reference pattern is measured after a development processing. By this measurement, long-term fluctuation of various factors of the projection exposure apparatus is measured and correction is made.

The factors to be measured and corrected by using the reference wafer are: long-term fluctuation of an alignment error between the reticle and the wafer; distortion of a projection optical system; mutual alignment error (a matching error) between the different exposure apparatuses; and the like. Specifically, these errors are measured by using the reference wafer, and a measurement value (an error amount) obtained is input to the projection exposure apparatus as an offset correction value. Thus, reduction of each kind of error on an actual process wafer is enabled.

Conventionally, as the reference wafer, a silicon wafer that has an uneven shape engraved on the surface was used, and its step pattern was made to be the reference pattern. Or a silicon wafer that has a pattern formed partially on the surface by a silicon dioxide film as the reference pattern has been used. In addition, for measurement of the positional shift of the resist image of the reticle mark relative to the reference pattern on the reference wafer, an optical positional shift measurement unit called a registration measurement unit

or a wafer alignment optical system built in the projection exposure apparatus is used.

Therefore, as each reference pattern, a step of about one fourth of a detection wavelength was set for the silicon step pattern and a thickness (a step) of about a half of the detection wavelength was set for the silicon dioxide film pattern, so that the optical position detection unit such as the registration measurement unit and the wafer alignment optical system can detect the pattern position easily. In this case, because the detection wavelength is from 500nm to 700nm, the above-described steps have been set about from 125nm to 350nm. Conventionally, the thickness of the resist coated on the wafer has been about 0.5μm.

Incidentally, resolution of the projection optical system needs to be improved with microfabrication of the integrated circuit. For this purpose, it is necessary for the exposure wavelength to be a shorter wavelength and the numerical aperture (N.A.) to be increased. Currently, an exposure apparatus having the exposure wavelength of 193nm is made as a prototype, where an ArF (argon fluorine) excimer laser light source is used. However, there is no photosensitive material (resist material) having high transmittance for such a short wavelength light, and the thickness of the photoresist coated on the wafer inevitably must be thinner than the above-described 0.5μm.

For future use, a prototype of an exposure apparatus with a light source of F_2 (fluorine) laser having the wavelength of 157nm, which is shorter than 193nm, is being considered.

However, under this wavelength, transmittance of the photoresist is even worse, and it is predicted that the exposure apparatus can be used only on a wafer having the resist thickness of about 0.1μm.

Coating of the photoresist on the wafer is performed by spin coating. If a step structure having the thickness of the resist to be coated or more exists on the wafer, coating unevenness called a striation occurs on the photoresist to be spin coated. Thus, uniform coating will be difficult. In other words, if ultra thin photoresist having the thickness of about 0.3μm or less was coated on the reference wafer made by the conventional step structure, the photoresist could not be coated uniformly due to the steps (various kinds of marks).

Accordingly, in the ArF exposure apparatus or the F_2 laser exposure apparatus having a shorter exposure wavelength than the ArF exposure apparatus, it is almost difficult to perform accuracy control by using the conventional reference wafer with the steps.

The present invention has been made under such circumstances. Its first object is to provide a reference wafer for accuracy control, in which there is no resist coating unevenness, good resist coating characteristic can be obtained, and practical use is enabled, even in the case where the resist needs to be coated ultra thin, and its manufacturing method.

In addition, a second object of the present invention is to provide an exposure apparatus in which overlay accuracy can be stably maintained for a long period of time and exposure of high resolution is enabled.

Further, a third object of the present invention is to provide a device manufacturing method, in which the productivity of an electronic device of high integration is improved.

DISCLOSURE OF INVENTION

The present invention, according to a first viewpoint, is a reference wafer for accuracy control used for accuracy control of an exposure apparatus, the reference wafer: consisting of a substrate (51) having a reference pattern formed on its surface; the reference pattern formed of a first area (54) having a first amplitude reflectivity and a second area (53) having a second amplitude reflectivity different from the first amplitude reflectivity; and the surface of the first area and the second area is made approximately flat.

According to this, the surface of the first area and the second area, which make up the reference pattern formed on the substrate surface, is made to be approximately flat. Therefore, even in the case where a photoresist (hereinafter, referred to as "resist") needs to be coated ultra thin (for example, a film thickness of about 0.3μm or less) on its surface, coating unevenness of the resist caused by the step between the surface of the first area and the surface of the second area does not occur, and good resist coating characteristic can be obtained.

In this case, it is preferable that planarization is performed on a step between a surface of the first area (54) and a surface of the second area (53) to preferably make the

step 100nm and under. In such a case, the coating unevenness of the resist does not occur at all even when the ultra thin resist having the film thickness of, for example, about 0.3μm or less is coated. Herein, it is more desirable that the step between the surface of the first area (54) and the surface of the second area (53) is smaller. For example, it is more desirable that the step is 50nm and under.

In the reference wafer for accuracy control of the present invention, the reference pattern may include a concave portion and a convex portion formed on the substrate (51), the first area (54) consisting of an area of the convex portion, and the second area (53) consisting of a pattern forming material embedded in the concave portion, the pattern forming material different from raw material of the substrate.

In this case, although it is matter of course that the pattern forming material may be an opaque material, the pattern forming material may also be a transparent material. Even in such a case, the amplitude reflectivity of the first area and the amplitude reflectivity of the second area that consist of the pattern forming material are apparently different. For this reason, discrimination between both areas is enabled in accordance with the difference of the amplitude reflectivity by an optical position measurement unit and the like. In addition, when the pattern forming material is a transparent material, it is desirable that the concave portion formed on the substrate has the depth of 50nm to 150nm. The detection wavelength used for detection of the reference wafer by the exposure apparatus is normally from 450nm to 800nm. For this

reason, a measurement error can be controlled to the minimum when the depth of the concave portions is in the vicinity of 1/4n times (n is an index of refraction of a thin film of the light transmission material, which is 1.5 to 2.0) of the detection wavelength.

Further, when the pattern forming material is a transparent material, a thin film of the transparent material may be formed on an area on the substrate that includes the first area and the second area. In such a case, a synthetic amplitude reflectivity of the first area and the second area is the sum of the amplitude reflectivity on the surface of the transparent material and the result of the amplitude reflectivity at the boundary between the thin film of the transparent material and the substrate multiplied by a phase shift amount of only a round trip of the thin film thickness. Accordingly, in the first area and the second area, the amplitude reflectivity is different in accordance with the thickness difference of the transparent material. For this reason, discrimination between both areas is enabled in accordance with the difference of the amplitude reflectivity by the optical position measurement unit and the like.

In the reference wafer for accuracy control of the present invention, it is desirable that the pattern forming material is a material having chemical resistance to acid cleaning. In such a case, it is possible to use it for a long period of time and stably.

Additionally, in the reference wafer for accuracy control of the present invention, the first area (54) may be formed

of a thin film made of a predetermined first material deposited on a portion of the substrate (51) surface excluding a partial area, and the second area (53) may be formed of a second material different from the first material, the second area formed on the partial area of the substrate surface. Specifically, on the substrate surface, the thin film of the first material and the second material having the amplitude reflectivity different from the first material may be embedded in the concave portions formed on the first material.

In this case, it is desirable that both the first material and the second material are materials having chemical resistance to acid cleaning. In such a case, it is possible to use it for a long period of time and stably.

In the reference wafer for accuracy control of the present invention, it is desirable that at least one of the first area and the second area is arranged on two orthogonal axes. In such a case, the area arranged on the orthogonal axes are made to be the reference pattern, thus control of a shot arrangement characteristic can be appropriately performed.

The present invention, according to a second viewpoint, is a first reference wafer manufacturing method to manufacture a reference wafer for accuracy control that is used for accuracy control of an exposure apparatus, the method comprising: a first step of depositing a thin film made of a predetermined first material on a substrate; a second step of performing patterning on the thin film and removing a part of the thin film; a third step of laminating a second material different from the first material substantially onto the entire surface

of the substrate including the thin film portion where the part of the thin film is removed; and a fourth step of performing planarization to the second material, until a first area made of the first material is exposed and a step between the first area made of the first material and a second area made of the second material becomes approximately flat.

According to this, the thin film made of the predetermined first material is deposited on the substrate, and subsequently, patterning is applied to the thin film to remove a part of the thin film. Next, the second material different from the first material is laminated substantially on the entire surface of the substrate including the thin film portion where an area is partially removed, and subsequently, the planarization is applied to the second material until the first area made of the first material is exposed to the surface and until the step between the first area made of the first material and the second area made of the second material becomes approximately flat. Accordingly, on the substrate surface, the first area formed of the thin film made of the predetermined first material deposited on the portion of the substrate surface except for a partial area, and the second area formed of the second material different from the first material, formed on the partial area of the substrate surface, are formed. In this case, the surface of the first area and the surface of the second area are approximately made flat, and the amplitude reflectivity is different between the first area and the second area. In the reference wafer manufactured in this manner, because discrimination between the first area and the second

area is possible by the optical position measurement unit and the like due to the difference of the amplitude reflectivity, these areas can be used as the reference pattern. In the case where the resist is coated ultra thin (for example, the film thickness at about 0.3μm or less) on the surface, coating unevenness of the resist caused by the steps between the surface of the first area and the surface of the second area does not occur, and good resist coating characteristic can be obtained.

In this case, the planarization may be performed to make the step between a surface of the first area and a surface of the second area be preferably 100nm and under, and more preferably 50nm and under, in the fourth step.

The present invention, according to a third viewpoint, is a second reference wafer manufacturing method to manufacture a reference wafer for accuracy control that is used for accuracy control of an exposure apparatus, the method comprising: a first step of removing a partial area on a surface of a substrate by patterning and etching; a second step of depositing a thin film made of a transparent material onto the surface of the substrate where the partial area is removed; and a third step of performing planarization to the thin film surface to make the entire surface of the thin film approximately flat.

According to this, the partial area of the substrate surface is removed by patterning and etching, and subsequently, the thin film made of the transparent material is formed so as to laminate the substrate surface where the partial area is removed. Next, the planarization is applied to the thin film surface to make the entire surface of the thin film

approximately flat. Accordingly, a concave portion is formed on a part of the substrate itself, and the thin film (its surface is made to be planer) made of the transparent material is formed so as to laminate the entire surface including the concave portion. In this case, the amplitude reflectivity of the thin film surface is the same on both the area corresponding to the concave portion of the substrate and the remaining area corresponding to the convex portion. And the synthetic amplitude reflectivity of each area is the sum of the amplitude reflectivity on the surface of the transparent material and the result of the amplitude reflectivity at the boundary between the thin film of the transparent material and the substrate multiplied by a phase shift amount of only a round trip of the thin film thickness. Accordingly, in the area corresponding to the convex portion and the area corresponding to the concave portion, the amplitude reflectivity is different in accordance with the thickness difference of the transparent material. Thus, discrimination between both areas is possible in accordance with the difference of the amplitude reflectivity by the optical position measurement unit and the like. Therefore, these areas can be used as the reference pattern. In the case where the resist is coated ultra thin (for example, the film thickness at about 0.3μm or less) on the surface, coating unevenness of the resist caused by the step between the surface of the area corresponding to the convex portion and the surface of the area corresponding to the concave portion does not occur, and good resist coating characteristic can be obtained.

In this case, the partial area on the surface of the substrate may be removed by 50nm to 150nm in depth, in the first step.

In the second reference wafer manufacturing method of the present invention, the method may further comprise: a fourth step of further performing the planarization until at least the surface of the substrate is exposed, after the planarization in the third step. In such a case, the surface of the reference wafer is mostly the substrate itself, and the transparent material is embedded only in small areas. Thus, there is little film stress on the substrate surface and there is little fear of the positional shift of each mark (reference pattern) occurring due to stress deformation associated with pattern formation.

The present invention, according to a fourth viewpoint, is an exposure apparatus that illuminates a mask (R) with an energy beam (EL), and sequentially transfers a pattern of the mask onto a plurality of shot areas on a sensitive substrate (W) via a projection optical system (PL), the exposure apparatus using the reference wafer for accuracy control according to the present invention to control overlay accuracy between the mask and the sensitive substrate.

According to this, since the overlay accuracy between the mask and the sensitive substrate is controlled by the use of the reference wafer for accuracy control in the present invention, even with the exposure apparatus using an energy beam with a short wavelength as an exposure light, where the transmittance of the energy beam is low and only ultra thin

resist can be coated, high overlay accuracy can be maintained stably for a long period of time by controlling the overlay accuracy between the mask and the substrate by the use of the reference wafer for the accuracy control. As a result, the pattern of the mask can be transferred onto the plurality of shot areas on the sensitive substrate with high resolution, and a multiple layer of patterns can be accurately overlaid and transferred by using the energy beam of the short wavelength as the exposure light.

Herein, the energy beam can be an Ar_2 laser beam, a Kr_2 laser beam, an F_2 laser beam, or a vacuum ultraviolet beam having the wavelength of 120nm to 200nm such as ArF excimer laser beam.

In this case, the control of the overlay accuracy may include at least one of controlling an image forming characteristic including distortion of the projection optical system, and a characteristic of an arrangement of a pattern image of the mask, which is sequentially transferred onto the substrate.

The present invention, according to a fifth viewpoint, is a device manufacturing method including a lithographic process, wherein exposure is performed using the exposure apparatus according to the present invention in the lithographic process.

According to this, by using the exposure apparatus of the present invention in which the stable and high overlay accuracy is maintained for a long period of time, and by performing exposure using the energy beam with the short

wavelength as the exposure light, it becomes possible to transfer a fine pattern onto a substrate with high resolution and good overlay accuracy stably for a long period of time. Therefore, the electronic device of high integration can be manufactured with good yield, and its productivity can be improved.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 a view schematically showing a constitution of an exposure apparatus according to a first embodiment, in which accuracy control is performed by using a reference wafer for accuracy control according to the present invention;

Fig. 2 is a block diagram schematically showing a constitution of a control system of the exposure apparatus of Fig. 1;

Fig. 3A is a plan view showing the reference wafer according to the first embodiment, and Fig. 3B is an A-A line sectional view of Fig. 3A;

Fig. 4A to Fig. 4C are views for explaining a manufacturing method of the reference wafer shown in Fig. 3A and Fig. 3B;

Fig. 5 is a plan view showing a sample of the reference wafer on which a large number of shot areas are formed;

Fig. 6A to Fig. 6C are views for explaining a reference wafer manufacturing method according to a second embodiment, and Fig. 6D is a view for explaining a reference wafer manufacturing method of a different type, where planarization is performed to the reference wafer completed at the stage of Fig. 6C;

Fig. 7 is a flowchart showing an embodiment of a device manufacturing method according to the present invention; and

Fig. 8 is a flow chart showing the processing in step 204 of Fig. 7.

Best Mode for Carrying out the Invention

- First embodiment

In the following, a first embodiment of the present invention will be described based on Fig. 1 to Fig. 4. Fig. 1 schematically shows a constitution of an exposure apparatus 100 according to the first embodiment in which accuracy control is performed by using a reference wafer for accuracy control according to the present invention. The exposure apparatus 100 is a scanning exposure apparatus (a so-called scanning stepper) based on the step-and-scan method, in which a reticle R as a mask and a wafer W as a sensitive substrate are moved synchronously in a predetermined scanning direction (herein, the X-axis direction that is a left and right direction on the paper of Fig. 1), and a pattern of the reticle R is transferred onto each shot area on the wafer W.

The exposure apparatus 100 comprises: an illumination system including a light source 1 and an illumination optical system; a reticle stage RST as a mask stage holding the reticle R; a projection optical system PL; a wafer stage WST as a substrate stage holding the wafer W; and the like.

As the light source 1, herein, an ArF excimer laser having an oscillation wavelength of 193nm or a pulse light source that emits a pulse ultraviolet beam such as an F_2 laser having

the oscillation wavelength of 157nm are used. Note that a KrF excimer laser having the oscillation wavelength of 248nm and the like may be used as the light source 1.

The illumination optical system is constituted by including: an illumination system housing 2; beam shaping lenses 3 and 4 arranged within the illumination system housing 2 in a predetermined positional relation; an optical integrator (an illumination uniformity optical system) 5 such as a fly eye lens; a beam splitter 6 having a large reflectivity and a small transmittance; relay lenses 7 and 9; a reticle blind 8 as an illumination field stop; a bending mirror 10; a condenser lens 11; and the like. In this case, the reticle blind 8 is constituted of a fixed reticle blind 8A, which is arranged at a plane de-focused a little from a conjugate plane relative to a pattern surface of the reticle R, and has a rectangular aperture for setting an illumination area IA formed on the reticle R, and of a movable reticle blind 8B arranged at the conjugate plane relative to the pattern surface of the reticle R in the vicinity of the fixed reticle blind 8A, and has an aperture portion where the position and the width corresponding to the scanning direction on the reticle R and a non-scanning direction perpendicular to the scanning direction are variable. The movable reticle blind 8B is designed to be controlled by a main controller 50 (not shown in Fig. 1, refer to Fig. 2), which will be described later, via a drive system 15. In the main controller 50, for example, the illumination area IA is further limited via the movable reticle blind 8B at a starting time and an ending time of a scanning exposure (described later),

thus exposure to an unnecessary portion is prevented.

Moreover, a light amount monitor 20 that consists of a photoelectric conversion element, which is called an integrator sensor, is arranged on a transmission optical path of the beam splitter 6. A photoconversion signal of the light amount monitor 20 is designed to be supplied to the main controller 50 (refer to Fig. 2).

Herein, operation of the illumination optical system is described briefly. Light in the ultraviolet region (a laser beam) LB emitted from the light source 1 is made to be incident to the optical integrator 5 via the beam shaping lenses 3 and 4. The laser beam LB is converted by the optical integrator 5 into illumination light for exposure (hereinafter, referred to as an "exposure light") EL having substantially uniform intensity distribution. The most part (about 97%, for example) of the exposure light EL is reflected by the beam splitter 6, and illuminates the reticle blind 8 with a uniform illuminance via the relay lens 7. The exposure light EL that has transmitted the aperture portion set by each blind constituting the reticle blind 8 illuminates the rectangular illumination area IA, which is set by the fixed reticle blind 8A, on the reticle R with a substantially uniform illuminance via the relay lens 9, the bending mirror 10 and the condenser lens 11.

On the other hand, the residual portion (about 3%, for example) of the exposure light EL that has transmitted the beam splitter 6 is received by the light amount monitor 20 for photoelectric conversion, and its photoelectric conversion signal is supplied to the main controller 50 (not shown in

Fig. 1, refer to Fig. 2). The main controller 50 is designed to control an exposure amount with the start of light emission from the light source 1 by controlling the light source 1 based on an output of the light amount monitor 20.

A reticle holder 13 is mounted on the reticle stage RST, and the reticle R is sucked and held by the reticle holder 13. The reticle holder 13 is designed to be finely driven (including rotation) within a horizontal plane (the XY plane), for example, by two pairs of voice coil motors constituting a reticle stage drive portion 23 (not shown in Fig. 1, refer to Fig. 2). In addition, the reticle stage RST is designed to be scanned in the X axis direction, which is the scanning direction, in a predetermined stroke range, by a linear motor and the like constituting the reticle stage drive portion 23. Specifically, in this embodiment, the reticle holder 13 (that is, the reticle R) can be finely driven within the XY plane by the reticle stage drive portion 23, and is driven in the X-axis direction in the predetermined stroke range.

The position of the reticle R is measured by a reticle laser interferometer system 16 via a moving mirror 14 fixed on the reticle holder 13, and a measurement value of the interferometer system 16 is supplied to the main controller 50 (refer to Fig. 2). Herein, on the reticle holder 13, a moving mirror having a reflection plane perpendicular to the X-axis direction and a moving mirror having a reflection plane perpendicular to the Y-axis direction are severally provided. In accordance with this, laser interferometers for measuring the X-axis direction position, measuring the Y-axis direction

position, and measuring the yawing are severally provided. In Fig. 1, these are representatively shown as the moving mirror 14 and the reticle laser interferometer system 16.

The projection optical system PL is, for example, a reduction system telecentric on both sides, and a refraction system or a reflection refraction system with a projection magnification β of 1/4, 1/5, 1/6 and the like is used. Accordingly, when the illumination area IA on the reticle R is illuminated by the exposure light EL as aforementioned, an image (a partially inverted image) of the pattern formed on the reticle reduced by the projection optical system PL by the projection magnification β is transferred onto a slit shaped exposure area on the wafer W on which the resist (photosensitive material) is coated, conjugate with the illumination area IA.

The wafer stage WST is designed freely movable within the XY plane by a wafer drive system 24 (not shown in Fig. 1, refer to Fig. 2) that consists of, for example, a two dimensional magnetically levitated linear actuator (a linear motor) and the like. A wafer holder 18 is mounted on the wafer stage WST, and the wafer W is held by suction by the wafer holder 18.

The position of the wafer stage WST is measured by a wafer laser interferometer system 21 via a moving mirror 19 fixed on the wafer holder 18, and a measurement value of the wafer laser interferometer system 21 is supplied to the main controller 50 (refer to Fig 2). Herein, on the wafer holder 18, a moving mirror having a reflection plane perpendicular

to the X-axis direction and a moving mirror having a reflection plane perpendicular to the Y-axis direction are provided. In accordance with this, laser interferometers for measuring the X-axis direction position, measuring the Y-axis direction position, and measuring the yawing (and measuring the pitching and measuring the rolling) are severally provided. In Fig. 1, these are representatively shown as the moving mirror 19 and the wafer laser interferometer system 21.

Moreover, a fiducial mark plate FM, on which a fiducial mark for base line measurement (hereinafter, referred to as a "first fiducial mark" for convenience) and a pair of fiducial marks for reticle alignment (hereinafter, referred to as "second fiducial marks" for convenience) are formed in a predetermined positional relation, is fixed on the wafer holder 18 such that the surface height of the fiducial mark plate FM is substantially equal to the surface of the wafer W. Note that the fiducial mark FM may be provided on the wafer stage WST.

Further, in the exposure apparatus 100, an off-axis wafer alignment detection system 22 for detecting the first fiducial mark on the fiducial mark plate FM or an alignment mark (a wafer mark) as a positioning mark provided in each shot area of the wafer W is fixed to the side of a lens barrel of the projection optical system PL. As the wafer alignment detection system 22, an imaging alignment sensor based on the image processing method is used here. The wafer alignment detection system 22 has an indicator, and is designed to supply the amount of the positional shift of the fiducial mark or the wafer mark

relative to the indicator center to the main controller 50 as a detection signal (refer to Fig. 2).

Still further, a pair of reticle alignment microscopes 12A and 12B of the through-the-reticle method are arranged between the illumination optical system and the reticle R (note that, in Fig. 1, the reticle alignment microscope 12B in the rear side on the paper is hidden behind the reticle alignment microscope 12A in the front side (refer to Fig. 2)). Herein, as the reticle alignment microscopes 12A and 12B, the imaging alignment sensor of the image processing method is used. In the reticle alignment microscopes 12A and 12B, a pair of reticle alignment marks (reticle marks) formed on the reticle R and a pair of the second fiducial marks formed correspondingly to this on the fiducial mark plate FM are simultaneously detected, and positional errors between both marks respectively corresponding to each other are supplied to the main controller 50 as the detection signal (refer to Fig. 2).

Fig. 2 schematically shows a constitution of the control system of the exposure apparatus 100. This control system is constituted centering the main controller 50. The main controller 50 is constituted by including a so-called micro computer (or a work station) that consists of: a CPU (a Central Processing Unit); a ROM (a Read Only Memory); a RAM (a Random Access Memory) and the like, and generally controls, for example, synchronous scanning of the reticle R and the wafer W, stepping of the wafer W, exposure timing and the like in order to perform accurate exposure operation.

Specifically, at the time of the scanning exposure, for

example, the main controller 50 respectively controls the position and the speed of the reticle stage RST and the wafer stage WST via the reticle stage drive portion 23 and the wafer drive system 24 respectively based on the measurement values of the laser interferometer systems 16 and 21 such that the wafer W is scanned in the -X direction (or the +X direction) at the velocity of $V_w=\beta \times V$ (β is the projection magnification from the reticle R to the wafer W) via the wafer stage WST synchronizing with the reticle R scanned in the +X direction (or the -X direction) at the velocity of $V_r=V$ via the reticle stage RST. In addition, at the time of the stepping, the main controller 50 controls the position of the wafer stage WST via the wafer drive system 24 based on the measurement value of the laser interferometer system 21.

Further, in the main controller 50, at the time of the aforementioned scanning exposure, the above-described exposure amount is adjusted or opening/closing operation of the movable reticle blind is controlled synchronizing with operation information of the stage system, in order to provide the wafer W a target exposure amount determined in accordance with exposure conditions and resist sensitivity.

Next, description will be made on exposure processing sequence where the circuit patterns on the reticle R are sequentially transferred onto a plurality of the shot areas, in which the patterns are already formed on the wafer W, centering on the control operation of the main controller 50.

Firstly, in the main controller 50, while monitoring the measurement value of the reticle laser interferometer

system 16, the reticle stage RST is moved to a position where a pair of the reticle alignment marks formed on the reticle R can be respectively detected by the reticle alignment microscopes 12A and 12B, via the reticle stage drive portion 23, for example, to a vicinity of the origin on a reticle stage coordinate system set by each measuring axis of the reticle laser interferometer system 16. Almost simultaneously with this, in the main controller 50, while monitoring the measurement value of the wafer laser interferometer system 21, the wafer stage WST is moved to a position where a pair of the second fiducial marks on the fiducial mark plate FM can be detected by the reticle alignment microscopes 12A and 12B via the wafer drive system 24.

Then, in the main controller 50, a relative positional detection of a pair of the second fiducial marks on the fiducial mark plate FM and a projection image of the corresponding reticle alignment marks on the wafer surface, that is, a reticle alignment, is performed by using the reticle alignment microscopes 12A and 12B having the exposure light EL as an alignment light beam.

Next, in the main controller 50, while monitoring the measurement value of the wafer laser interferometer system 21, the wafer stage WST is moved to a position where the first fiducial mark on the fiducial mark plate FM can be detected by the wafer alignment detection system 22 via the wafer drive system 24, based on a relative positional relation (a design value) between the optical axis (the center of an exposure area conjugate with the illumination area) of the projection

optical system PL and the wafer alignment detection system 22. Then, in the main controller 50, the amount of the positional shift of the first fiducial mark relative to the indicator center of the wafer alignment detection system 22 is detected by using the wafer alignment detection system 22. And the base line amount, which is the positional relation between a projection position of the reticle pattern and a detection center of the wafer alignment detection system 22, is calculated based on this detection result, a detection result of the relative position at the time of the above-described reticle alignment, and the above-described design value. Specifically, the base line measurement is performed in this manner.

Note that the base line measurement can be performed simultaneously with the above-described reticle alignment when the fiducial mark plate of a large size (a large fiducial mark plate), on which the first fiducial mark and a pair of the second fiducial marks are formed in a predetermined positional relation such that they can be simultaneously measured by the wafer alignment detection system 22 and a pair of the reticle alignment microscopes 12A and 12B respectively, is used as the fiducial mark plate FM.

Note that preparation work for the above-described fiducial mark plate FM, the reticle alignment, the base line measurement and the like are described in detail, for example, in Japanese Patent Laid-Open (Unexamined) No. 04-324923 and the corresponding United States Patent No. 5,243,195. As long as the national laws in designated states or elected states,

to which this international application is applied, permit, the disclosures cited above are fully incorporated herein by reference.

Next, in the main controller 50, the positions of three search alignment marks (not shown) formed on the wafer W mounted on the wafer stage WST are sequentially measured by using the wafer alignment detection system 22, and a search alignment is performed in which the positional error relative to the design value of the wafer W in the directions of X, Y and θ is calculated based on the measurement result. Note that the search alignment is described in detail, for example, in Japanese Patent Laid-Open 02-272305, and the corresponding United States Patent No. 5,151,750. As long as the national laws in designated states or elected states, to which this international application is applied, permit, the disclosures cited above are fully incorporated herein by reference.

After completion of the search alignment, in the main controller 50, the wafer mark positions of at least three shot areas being sample shots selected from a plurality of the shot areas are measured by using he wafer alignment detection system 22, while controlling the position of the wafer stage WST based on the measurement value of the wafer laser interferometer system 21 and while sequentially moving the wafer stage WST based on a designed shot arrangement data (wafer mark positional data) and the result of the search alignment. Then, fine alignment based on the enhanced global alignment (EGA) method is performed to obtain all the shot arrangement data by statistical calculation by the least-squares method, based

on the measurement value and design coordinate data of the shot arrangement. Note that the alignment method of the EGA method is described in detail, for example, in Japanese Patent Laid-Open No. 61-44429, and corresponding the United States Patent No. 4,780,617. As long as the national laws in designated states or elected states, to which this international application is applied, permit, the disclosures cited above are fully incorporated herein by reference.

Next, in the main controller 50, the wafer stage WST is moved to a scanning starting position for an exposure of a first shot on the wafer W based on the above-described base line measurement result and the result of the fine alignment. Then, the foregoing scanning exposure is performed by moving the reticle stage RST and the wafer stage WST synchronously in the scanning direction (X-axis direction), and the pattern of the reticle R is transferred onto the first shot on the wafer W. Next, in the main controller 50, the wafer stage WST is moved (stepping) to the scanning starting position of the next shot at least in X-axis direction for a second shot exposure, and the above-described scanning exposure is performed to the second shot.

Thereafter, in the main controller 50, the above-described moving operation (the stepping operation) between the shots and the scanning exposure operation are sequentially repeated, and the pattern formed on the reticle R is transferred onto each shot area on the wafer W by the step-and-scan method.

As described above, when the exposure on a slice of wafer

is completed, wafer exchange is performed by a wafer loader system (not shown) and an exchange mechanism on the wafer stage, and then, the above-described alignment processing (the search alignment and the fine alignment) and the exposure processing are repeatedly performed to the wafer after the exchange.

In the exposure apparatus 100, transfer of the reticle pattern onto a plurality of wafers is repeatedly performed as described above. Since overlay error between the reticle pattern and the shot areas on the wafer W occurs with passage of time due to temperature change or atmospheric pressure change, and other various factors in a semiconductor factory where the exposure apparatus 100 is installed, as described above, each kind of factors that become the factors for the overlay error is strictly controlled by the use of the reference wafer for accuracy control. As the factors to be controlled by using the reference wafer for accuracy control, for example, an image forming characteristic of the projection optical system PL (for example, a distortion), an arrangement of the reticle pattern image transferred onto the wafer, that is, an arrangement characteristic of the shot areas, a stepping accuracy of the wafer stage, the positional shift between the shot areas, and the like are cited representatively.

In the following, description will be made for a reference wafer for accuracy control (hereinafter, referred to as a "wafer for reference") according to the present invention used for the accuracy control of the exposure apparatus 100 and other exposure apparatuses, and its manufacturing method.

Fig. 3A shows a plan view of a reference wafer W1 according

to the first embodiment, and Fig. 3B shows an A-A line sectional view of Fig. 3A.

The reference wafer W1, as apparent when Fig. 3A and Fig. 3B are unified, comprises a substrate (wafer) 51 consisting of silicon or synthetic quartz, and a thin film 54 made of a predetermined first material is deposited substantially on the entire surface of the surface (the upper surface) of the substrate 51. As the first material, material such as silicon dioxide, silicon nitride, polysilicon and the like having low reflectivity in comparison with metal are used, and a first area having the low reflectivity (a first amplitude reflectivity) is formed by the thin film 54. In the following description, the first area is represented as the first area 54 using the same reference numeral as the thin film.

In this case, as shown in Fig. 3A, a plurality (four in this case) of divided areas 52a to 52d are provided in the first area 54. In each divided area, mark areas 53_1 to 53_n are provided as a second area, in which a plurality of marks are formed in the same arrangement. These mark areas 53_1 to 53_n are formed by a second material, for example, metal such as tungsten, aluminum, titanium and platinum or its nitride, embedded in openings (holes) of a predetermined shape formed in a part of the thin film 54 forming the divided areas 52a to 52d. Therefore, the mark areas 53_1 to 53_n have high reflectivity (second amplitude reflectivity), and the reference pattern is formed of the first area 54 having a different surface amplitude reflectivity and the mark areas 53_1 to 53_n. In the following description, the mark areas 53_1

to 53_n are collectively called as "mark area 53" as appropriate.

Since the reference wafer W1 is used for accuracy control for the above-described projection exposure apparatus 100 and other exposure apparatuses, for example, other exposure apparatus used in the same semiconductor manufacturing line as the projection exposure apparatus 100, patterns suitable for accuracy control are actually formed on the mark area 53. Specifically, an alignment mark (a wafer alignment mark) for controlling the alignment accuracy of the projection exposure apparatus, a mark for measuring the alignment shift, a mark for measuring the distortion (a mark for measuring the alignment shift) to measure the distortion of the projection optical system that the exposure apparatus has, and the like are formed. Note that the mark for measuring the alignment shift will be further described later.

In the reference wafer W1, the step between the surface of the first area 54 and the surface of the mark area 53 is 50nm or less.

Herein, a manufacturing method of the reference wafer W1 will be described based on Fig. 4A to Fig. 4C.

(1) Firstly, the first area (thin film) 54 is deposited substantially on the entire surface of the substrate 51, and photosensitive material (resist) is subsequently coated on the entire surface of the first area by using a resist coating unit (a coater) (not shown). Then, the substrate 51 where the resist is coated is loaded on the wafer holder 18 of the foregoing exposure apparatus 100, and a reticle (not shown) for the reference wafer (a special reticle on which a pattern of the

reference pattern is magnified and formed) is loaded on the reticle stage RST, and the pattern of the reticle for the reference wafer is reduced and transferred onto the substrate 51 based on the step-and-scan method as described above. Accordingly, the image of the reference pattern is transferred and formed on a plurality of the shot areas (the four shot areas in this case) on the substrate 51.

Next, the substrate 51 to which the exposure is completed is unloaded from the wafer holder 18, and development is performed by using a development unit (a developer) (not shown). Accordingly, a resist image of the reference pattern is formed on the surface of the substrate 51.

Then, etching processing is performed to the substrate 51 to which the development processing is completed by using an etching unit (not shown) until the surface of the substrate 51 is exposed. Subsequently, the resist left on the surface of the substrate to which the etching processing is completed is removed by using, for example, a plasma ashing apparatus or the like.

Accordingly, as shown in Fig. 4A, the first area 54 is formed on the surface of the substrate 51, where a partial area that ultimately becomes the mark area 53 is removed and a concave portion 53' is formed. Specifically, patterning of the thin film on the surface of the substrate 51 is performed in this manner to form the first area 54 (having the concave portion 53' here and there) on the surface of the substrate 51.

(2) Next, as shown in Fig. 4B, a film 55 of the metal or its

nitride is formed on the entire surface of the substrate 51 including the first area 54 by sputter deposition or CVD.

(3) Next, a predetermined planarization processing, for example, CMP (chemical mechanical polishing) is applied to the surface of the film 55, and the mark area 53 made of the metal or its nitride is formed in the concave portion 53', as shown in Fig. 4C. In this case, the planarization processing is performed by the CMP such that the step between the surface of the first area 54 and the surface of the mark area 53 becomes 50nm or less.

Note that, as the planarization processing, it is acceptable that a processing is enabled where the step between the surface of the first area 54 and the surface of the mark area 53 ultimately becomes 100nm or less, preferably 50nm or less, and such processing is not limited to the above-described CMP. For example, as the planarization processing, a planarization processing is acceptable in which SOG (spin-on-glass) or the like is coated on the film 55 after it is formed and the SOG is etched back. Otherwise, as shown in Fig. 4A, the planarization can be performed by allowing tungsten (W), for example, to be selectively deposited on the concave portions 53' of the substrate 51 where the first area 54 is formed by using a selective CVD unit.

Next, description will be made for the accuracy control of the exposure apparatus 100, which is performed by using the reference wafer W1 manufactured as described above.

As a premise, each reference pattern formed on the above-described reference wafer W1, that is, mark information

regarding positions (coordinate values) and line widths of the wafer alignment mark, the mark for alignment shift measurement, the mark for distortion measurement and the like is accurately measured by using the wafer alignment detection system 22 (or other coordinate measurement units such as an optical interferometric coordinate measurement unit) of the exposure apparatus 100, and its measurement result is stored.

Then, actual accuracy control of the exposure apparatus 100 is performed as follows. Specifically, the resist is coated on the reference wafer W1, for example, in the thickness of 0.1 to 0.2μm, the reference wafer W1 after coating resist is loaded on the wafer holder 18, and a test reticle having a mark for alignment shift measurement (to be called as a "test mark" for convenience) that makes a pair with the reference patterns severally formed on the reference wafer W1, that is, the mark for alignment shift measurement, is loaded on the reticle holder 13. And then, exposure processing is performed as described above to overlay and transfer the pattern of the test reticle onto the reference wafer W1. The reference wafer W1 to which the exposure is completed is unloaded from the wafer holder 18, and developed by the development unit. Accordingly, the resist image of the test mark is formed on the surface of the reference wafer W1.

Next, by the use of the wafer alignment detection system 22 (or the optical positional shift measurement unit such as the registration measurement unit) of the exposure apparatus 100, a relative positional relation is measured between each reference pattern on the reference wafer W1 and the

corresponding resist image of the test mark. And, the overlay error of the exposure apparatus 100 and the distortion value of the projection optical system PL are calculated based on the measurement result. Accordingly, accuracy control of the exposure apparatus 100 is enabled.

Note that, as the mark for alignment shift measurement making the pair, a method of using a mark called a box-in-box mark is representatively cited. In the case where such a box-in-box mark is used, for example, a square mark pattern of around 20μm to 30μm squares is formed as the reference pattern on the reference wafer W1 side, and on the reference pattern the resist image of the test mark pattern of around 10μm to 20μm squares is formed. The positional shift between these patterns is measured.

Alternatively, a linear pattern or a grid pattern may be formed on both the reference wafer W1 and the test reticle, and the alignment shift between the patterns may be measured.

Note that in the above description, the four shot areas 52a to 52d are formed on the reference wafer W1 for convenience of explanation. However, since a large number of shot areas are formed on the wafer W that is actually used in the semiconductor manufacturing process (hereinafter, referred to as an "processing wafer W" as appropriate), it is desirable that a large number of shot areas are formed identically on the reference wafer W1, as is with the processing wafer W. Fig. 5 shows an example of the reference wafer on which such large number of shot areas are formed. On the reference wafer W1' shown in Fig. 5, thirty three shot areas S_1 to S_{32} are formed

in total, and reference patterns (the reference marks) M_1 to M_5 are formed at five positions in total; at the four corner portions of each shot area and the shot center. For example, a constitution is made such that these reference patterns M_1 to M_5 respectively include the alignment mark where positional measurement in X and Y directions is enabled and the alignment shift measurement mark.

With this constitution, arrangement error of a transferred image of the reticle pattern by the exposure apparatus 100, that is, error regarding the shot arrangement characteristic, magnification error of the projection optical system PL, distortion, stepping error of the wafer stage and the like, can be controlled independently for each shot area by the use of the reference wafer W1'.

Note that the exposure apparatus 100 has the arrangement error of each shot and the distortion error of the projection optical system PL, even when the reference wafer W1 according to the embodiment is manufactured. Therefore, when the reference wafer W1 is used for accuracy control of the exposure apparatus 100, it is desirable that the positional error of the reference patterns (the measurement marks) formed on each of the mark area 53 on the reference wafer W1 is controlled as an offset. Of course, the reference wafer W1 may be manufactured by using other exposure apparatus, for example, an exposure apparatus used in the same manufacturing line as the exposure apparatus 100. In such a case, similar to the foregoing, it is desirable that the position of each reference pattern formed on the reference wafer W1 is measured and the

positional error of each reference pattern is controlled as the offset based on the measurement result. Note that the image forming characteristic of the projection optical system may be adjusted by moving its lenses.

Since manufacturing error also occurs on the test reticle, it is desirable that the position of each mark on the test reticle is also accurately measured and the positional error is controlled as an offset.

Note that an accuracy control method of the exposure apparatus is disclosed in detail, for example, in Japanese Patent Laid-Open No. 07-99148, and the corresponding United States Patent No. 5,798,195 and the like. As long as the national laws in designated states or elected states, to which this international application is applied, permit, the disclosures cited above are fully incorporated herein by reference.

As described above, on the reference wafer W1 of the embodiment, since the step between the surface of the mark area 53 and the surface of the other area (the first area) 54 is 50nm or less, uniform coating of the ultra thin photoresist of the thickness of about 0.3μm or less is enabled, which has been difficult in a conventional reference wafer. Specifically, in the reference wafer W1, good resist coating characteristic can be obtained even in the case where the photoresist is required to be coated ultra thin, because the coating unevenness caused by the steps does not occur.

Therefore, the reference wafer W1 can be put to practical use as a highly accurate reference wafer in an exposure apparatus

using the F_2laser beam having the wavelength of 157nm or the like as the exposure light where the resist film thickness is required to be controlled at about 0.1μm or less, without mentioning the exposure apparatus using the ArF laser beam having the wavelength of 193nm as the exposure light where the resist film thickness is required to be controlled at about 0.3μm or less.

Moreover, since the reference wafer W1 is the one used for accuracy control of the exposure apparatus 100 for a long period of time, periodical cleaning is required to remove adhered dust, contaminants, and the like generated during the use. Accordingly, each material that constitutes the reference wafer W1 is required to have chemical resistance to the cleaning, particularly, to acid cleaning. In the reference wafer W1 of the embodiment, as described above, the first area 54 and the mark area 53 as the second area are formed by using materials having excellent resistance to acid washing such as metal (silicon dioxide, silicon nitride, tungsten, titanium or the like), or its oxide, aluminum oxide, and the like. Thus, the reference wafer W1 can be stably used for a long period of time.

In addition, since the overlay accuracy of the exposure apparatus 100 of the embodiment is controlled as described above by using the foregoing reference wafer W1, accuracy control of high accuracy and high reliability is enabled. Accordingly, with the exposure apparatus 100, fine patterns can be transferred onto the wafer W in high resolution and good overlay accuracy stably for a long period of time, using

a pulse ultraviolet beam of a short wavelength such as the laser beam of ArF having the wavelength of 193nm or the laser beam of F_2 having the wavelength of 157nm and the like as the illumination light for exposure.

Note that, in the above-described embodiment, description was made for the case where the reference wafer W1 is used for accuracy control of the exposure apparatus 100 used for manufacturing the wafer. Not limited to this, the reference wafer W1 can be preferably applied to other exposure apparatus, for example, other ArF excimer laser exposure apparatus or F_2 laser exposure apparatus in the same manufacturing line as the exposure apparatus 100, or other exposure apparatus.

- Second embodiment

Next, a second embodiment of the present invention will be described based on Fig. 6A to Fig. 6C. In Fig. 6A to Fig. 6C, flow of the manufacturing process of a reference wafer W2 according to the second embodiment is shown. In the following, the manufacturing method of the reference wafer W2 will be described based on the drawings.

a. Firstly, a photosensitive material (resist) is substantially coated on the entire surface of the substrate 51 by using the resist coating unit (the coater) (not shown). Then, the substrate 51 where the resist is coated is loaded on the wafer holder 18 of the foregoing exposure apparatus 100, and the reticle (not shown) for the reference wafer is loaded on the reticle stage RST, and the pattern of the reticle for the reference wafer is transferred onto the substrate 51 based

on the sep-and-scan method as described above. Accordingly, a projection image of the reference pattern is formed on a plurality of the shots (in this case, it is also desirable that the same number of shots as the shot areas are formed on the processing wafer W) on the substrate 51.

Next, the substrate 51 to which the exposure is completed is unloaded from the wafer holder 18, and development is performed by using the development unit (the developer) (not shown). Accordingly, the resist image of the reference pattern is formed on the surface of the substrate 51.

Then, etching processing is applied to the substrate 51 to which the development processing was completed by using the etching unit (not shown) until the substrate 51 is engraved by a little amount. Subsequently, the resist left on the surface of the substrate to which the etching processing is completed is removed by using, for example, the plasma asher or the like.

Accordingly, as shown in Fig. 6A, the substrate 51 is provided where a partial area that ultimately becomes the mark area 53 is removed and a concave portion 53' is formed. Specifically, patterning of the thin film on the surface of the substrate 51 is performed in this manner to form the concave portions, which should be the reference patterns, on the substrate 51.

b. Next, as shown in Fig. 6B, a film 54 of silicon dioxide, silicon nitride or the like is formed on the entire surface of the substrate 51 by the CVD method or the like.

After the thin film 54 is formed, the surface 55 of the

thin film on the concave portion 53' is grooved in accordance with engraving of the substrate 51.

c. Next, as shown in Fig. 6C, the surface of the thin film 54 is made to be flat until the step becomes about 50nm or less by the foregoing CMP method or etch back method. Accordingly, the reference wafer W2 is completed.

Herein, in the case of the reference wafer W2, the reflectivity of only the surface of the thin film is the same on the first area 54 portion and on the mark area 53 portion as the second area. However, since the thin film is made of silicon oxide or silicon nitride having transmittance, the synthetic reflectivity becomes the sum of the amplitude reflectivity on the thin film surface and the result of the amplitude reflectivity at the boundary between the thin film and the substrate multiplied by a phase shift amount of only a round trip of the thin film thickness. Accordingly, in the mark area 53 and the remaining first area 54, the amplitude reflectivity is different in accordance with the thickness difference of the thin film. And, discrimination between both areas is enabled in accordance with the difference of the amplitude reflectivity by the alignment detection system 22 or the like. Accordingly, the mark area 53 can be respectively used as the mark for positional detection or the mark for measuring alignment shift.

Note that a reference wafer W2' as shown in Fig. 6D may be manufactured when polishing or the like is further progressed from the state of Fig. 6C until the surface of the substrate 51 is exposed. In this case, it is needless to say that the

amplitude reflectivity of the first area 54 and the second areas 53 is different from each other.

Herein, in both cases of Fig. 6C and Fig. 6D, it is desirable that the depth of the mark area engraved on the substrate 51 is 50nm to 150nm. This is because the detection wavelength of the alignment detection system 22 used in the positional detection (the wafer alignment) by the exposure apparatus and the wavelength of an inspection light used by the registration measurement unit are 450nm to 800nm, and the measurement error can be controlled at the minimum when the depth of the mark area is in the vicinity of 1/4n times (n is an index of refraction of the thin film, which is 1.5 to 2.0) of the wavelength.

Accuracy control of the exposure apparatus 100 and other exposure apparatus is performed as described in the foregoing first embodiment by the use of the reference wafer W2 (or W2') of the second embodiment manufactured in this manner.

As described above, in the reference wafer W2 (or W2') of the second embodiment, since the step between the surface of the mark area 53 and the surface of the other area (the first area) 54 is 50nm or less, uniform coating of the ultra thin photoresist of the thickness of about 0.3μm or less, is enabled. Therefore, the reference wafer W2 (or W2') can be put to practical use as a highly accurate reference wafer in an exposure apparatus where the laser beam of F_2 having the wavelength of 157nm is used as the exposure light, not to mention an exposure apparatus where the laser beam of ArF having the wavelength of 193nm is used as the exposure light.

Moreover, since the material that constitutes the reference wafer W2 (or W2') is formed by using raw materials such as silicon dioxide, silicon nitride or the like having excellent chemical resistance to acid washing, the reference wafer W2 (or W2') can be stably used for a long period of time.

In particular, as shown in Fig. 6D, in the reference wafer W2', most of the surface of the reference wafer W2' is the silicon substrate itself and silicon dioxide is buried only in small areas. Thus, there is little film stress on the substrate surface and it is advantageous that there is little fear of the positional shift of each mark occurring due to the stress deformation associated with the pattern formation.

In addition, since the overlay accuracy of the exposure apparatus 100 and other exposure apparatus is controlled by using the reference wafer W2 (or W2'), accuracy control of high accuracy and high reliability is enabled. Accordingly, by using the exposure apparatus 100 and the like, fine patterns can be transferred onto the wafer W in high resolution stably for a long period of time, when the pulse ultraviolet beam of a short wavelength such as the ArF laser beam having the wavelength of 193nm, the F2 laser beam having the wavelength of 157nm, or the like is used as the illumination light for exposure.

Note that, in each of the above-described embodiment, description was made for the reference wafer having a plurality of shot areas (the divided areas). The reference wafer for accuracy control according to the present invention is not limited to this. Specifically, the divided areas are not

necessarily formed on the reference wafer for accuracy control according to the present invention. However, it is desirable that the reference patterns on the reference wafer are disposed on two orthogonal axes. This is because it is necessary for controlling the shot arrangement characteristic.

In addition, in each of the above-described embodiment, description was made on the case where accuracy control of the exposure apparatus is performed by using the reference wafer according to the present invention, in which the ArF excimer laser, F_2 laser or the like is used as the exposure light source. The application range of the present invention is not limited to this. Further, in each of the above-described embodiment, the position of each mark is detected after the reference wafer W on which the test mark is formed is developed. However, the position of each mark may be detected in the state of a latent image, without performing development.

The reference wafer according to the present invention can be preferably applied to the control of overlay accuracy, the control of the stepping accuracy of the wafer stage, the positional shift between the shot areas, and the like of an exposure apparatus that uses a light source that emits light belonging to vacuum ultraviolet region (the wavelength between about 120nm and about 180nm), for example, a krypton dimer laser having the oscillation wavelength of 146nm (Kr_2 laser) or an argon dimer laser (Ar_2 laser) having the oscillation wavelength of 126nm, not to mention an ultra high pressure mercury lamp that emits a bright ray (g-ray and i-ray) and the like in an far-ultraviolet region.

Even in the case where an exposure light having the same wavelength band region as the exposure apparatus 100 of the foregoing embodiment is used, not limited to the ArF excimer laser beam and the like referred to above, a harmonic may be used as the illumination light for exposure. The harmonic is generated, for example, by amplifying a single-wavelength laser beam in the infrared or visible region oscillated from a DFB semiconductor laser or a fiber laser with an erbium (or both of erbium and ytterbium) doped fiber amplifier, and by converting the wavelength of the laser beam into an ultraviolet light by using a non-linear optical crystal. Specifically, supposing the oscillation wavelength of the single wavelength laser is within the range of 1.51μm to 1.59μm, an eighth-harmonics having the generation wavelength within the range of 189nm to 199nm or a tenth-harmonics having the generation wavelength within the range of 151nm to 159nm is output. Note that an ytterbium doped fiber or the like can be used as the single wavelength oscillation laser.

Incidentally, in the case where the exposure apparatus uses the light source having the wavelength in the vacuum ultraviolet region such as the above-described fluorine laser (wavelength of 157nm) or the like, a gas environment in the vicinity of the above-described reticle stage and the vicinity of the wafer stage, not to mention a light path of the exposure luminous flux in the projection optical system and the illumination optical system, must be replaced by gas having small absorption to the light of the exposure wavelength, for example, low absorptive gas such as helium, argon, nitrogen,

krypton or a concentration of the gases. To replace the gas in the vicinity of the wafer stage and the reticle stage, these stages need to be covered with a partition wall surrounding their periphery and the inside of the partition wall needs to be replaced by the gas. In addition, in the case of supporting these stages with a gas hydrostatic bearing, a gas hydrostatic bearing that exhausts the above-described low absorptive gas onto a guide surface needs to be used as the gas hydrostatic bearing.

Moreover, in the foregoing embodiments, description was made for the case where the present invention was applied to the scanning exposure apparatus. Not limited to this, the present invention may be applied to an exposure apparatus of step-and-repeat type in which the pattern of the mask is transferred onto the substrate while the mask and the substrate are in a static state and the substrate is sequentially moved in steps.

The application of the exposure apparatus is not limited to the exposure apparatus for manufacturing the semiconductor device. For example, the exposure apparatus can be widely applied to an exposure apparatus for liquid crystals where a liquid crystal display device pattern and a plasma display pattern are exposed on a square glass plate, and to an exposure apparatus for manufacturing a thin film magnetic head and a pick-up device.

- Device Manufacturing Method

A device manufacturing method using the exposure apparatus described above in a lithographic process will be

described next.

Fig. 7 is a flow chart showing an example of manufacturing a device (a semiconductor chip such as an IC or LSI, a liquid crystal panel, a CCD, a thin magnetic head, a micromachine, or the like). As shown in Fig. 7, in step 201 (design step), function/performance is designed for a device (e.g., circuit design for a semiconductor device) and a pattern to implement the function is designed.

In step 202 (mask manufacturing step), a mask on which the designed circuit pattern is formed is manufactured.

In step 203 (wafer manufacturing step), a wafer is manufacturing by using a silicon material or the like.

Next, in step 204 (wafer processing step), an actual circuit and the like is formed on the wafer by lithography or the like using the mask and wafer prepared in steps 201 to 203, as will be described later. Then, in step 205 (device assembly step) a device is assembled using the wafer processed in step 204. Step 205 includes processes such as dicing, bonding, and packaging (chip encapsulation).

Finally, in step 206 (inspection step), a test on the operation of the device, durability test, and the like are performed. After these steps, the device is completed and shipped out.

Fig. 8 is a flow chart showing a detailed example of step 204 described above in manufacturing the semiconductor device. Referring to Fig. 8, in step 211 (oxidation step), the surface of the wafer is oxidized. In step 212 (CVD step), an insulating film is formed on the wafer surface. In step

213 (electrode formation step), an electrode is formed on the wafer by vapor deposition. In step 214 (ion implantation step), ions are implanted into the wafer. Steps 211 to 214 described above constitute a pre-process for the respective steps in the wafer processing and are selectively executed in accordance with the processing required in the respective steps.

When the above pre-process is completed in the respective steps in the wafer process, a post-process is executed as follows. In this post-process, first, in step 215 (resist formation step), the wafer is coated with a photosensitive agent. Next, as in step 216 (exposure step), the circuit pattern on the mask is transcribed onto the wafer using the exposure apparatus 100 in the embodiments above.

Then, in step 217 (developing step), the exposed wafer is developed. In step 218 (etching step), an exposed member on a portion other than a portion where the resist is left is removed by etching. Finally, in step 219 (resist removing step), the unnecessary resist after the etching is removed.

By repeatedly performing these pre-process and post-process steps, multiple circuit patterns are formed on the wafer.

As described above, according to the device manufacturing method of the embodiment, in the exposure process (step 216), the exposure apparatus 100 which overlay accuracy is controlled with by the reference wafer W1, W1', W2, or W2' and the overlay accuracy maintained at high precision for a long period of time is used, and exposure is performed with a pulse ultraviolet light having a short wavelength serving as the illumination

light for exposure, such as the ArF excimer laser (wavelength: 193nm), the F_2 laser beam, and the like. This allows a fine pattern to be transferred onto a wafer W with high resolution, stably for a long period of time, with excellent overlay accuracy. Accordingly, a highly integrated electronic device can be manufactured with high yield, thus the productivity can be improved.

INDUSTRIAL APPLICABILITY

As is described, the reference wafer for accuracy control related to the present invention is suitable for controlling the overlay accuracy of the exposure apparatus. In addition, the exposure apparatus related to the present invention is suitable to form a fine pattern onto a substrate such as a wafer in a lithographic process when manufacturing microdevices such as an integrated circuit. And, the device manufacturing method according to the present invention is suitable to manufacture a high integration device having a fine pattern.

1, 14, 16, 19

WHAT IS CLAIMED IS:

1. A reference wafer for accuracy control used for accuracy control of an exposure apparatus, said reference wafer:

consisting of a substrate having a reference pattern formed on its surface;

said reference pattern formed of a first area having a first amplitude reflectivity and second area having a second amplitude reflectivity different from said first amplitude reflectivity; and

a surface of said first area and said second area is made approximately flat.

2. The reference wafer for accuracy control according to Claim 1, wherein planarization is performed on a step between a surface of said first area and a surface of said second area to preferably make said step 100nm and under, and more preferably, to 50nm and under.

3. The reference wafer for accuracy control according to Claim 1, wherein said reference pattern includes a concave portion and a convex portion formed on said substrate,

said first area consisting of an area of said convex portion, and

said second area consisting of a pattern forming material embedded in said concave portion, said pattern forming material different from raw material of said substrate.

4. The reference wafer for accuracy control according to Claim 3, wherein said pattern forming material is an opaque material.

5. The reference wafer for accuracy control according to Claim 3, wherein said pattern forming material is a transparent material.

6. The reference wafer for accuracy control according to Claim 5, wherein said concave portion formed on said substrate has the depth of 50nm to 150nm.

7. The reference wafer for accuracy control according to Claim 5, wherein a thin film of said transparent material is formed on an area on said substrate that includes said first area and said second area.

8. The reference wafer for accuracy control according to Claim 3, wherein said pattern forming material is a material having chemical resistance to acid cleaning.

9. The reference wafer for accuracy control according to Claim 3, wherein said pattern forming material is any one of silicon dioxide, silicon nitride, tungsten, titanium, oxide of these metals, and oxide of aluminum.

10. The reference wafer for accuracy control according

to Claim 1, wherein

said first area is formed of a thin film made of a predetermined first material deposited on a portion of said substrate surface excluding a partial area, and

said second area is formed of a second material different from said first material, said second area formed on said partial area of said substrate surface.

11. The reference wafer for accuracy control according to Claim 1, wherein both said first material and said second material are materials having chemical resistance to acid cleaning.

12. The reference wafer for accuracy control according to Claim 10, wherein said pattern forming material is any one of silicon dioxide, silicon nitride, tungsten, titanium, oxide of these metals, and oxide of aluminum.

13. The reference wafer for accuracy control according to Claim 1, wherein at least one of said first area and said second area is arranged on two orthogonal axes.

14. A reference wafer manufacturing method to manufacture a reference wafer for accuracy control that is used for accuracy control of an exposure apparatus, said method comprising:

FB. pg 10, l 23 - pg 11, l 3 different + separately

a first step of depositing a thin film made of a predetermined first material on a substrate;

a second step of performing patterning on said thin film and removing a part of said thin film;

a third step of laminating a second material different from said first material substantially onto the entire surface of the substrate including said thin film portion where said part of said thin film is removed; and

a fourth step of performing planarization to said second material, until a first area made of said first material is exposed and a step between said first area made of said first material and a second area made of said second material becomes approximately flat.

15. The reference wafer manufacturing method according to Claim 14, wherein said planarization is performed to make said step between a surface of said first area and a surface of said second area be preferably 100nm and under, and more preferably 50nm and under, in said fourth step.

16. A reference wafer manufacturing method to manufacture a reference wafer for accuracy control that is used for accuracy control of an exposure apparatus, said method comprising:

a first step of removing a partial area on a surface of a substrate by patterning and etching;

a second step of depositing a thin film made of a transparent material onto said surface of said substrate where said partial area is removed; and

a third step of performing planarization to said thin

film surface to make the entire surface of said thin film approximately flat.

17. The reference wafer manufacturing method according to Claim 16, wherein, said partial area on said surface of said substrate is removed by 50nm to 150nm in depth, in said first step.

18. The reference wafer manufacturing method according to Claim 16, said method further comprising:

a fourth step of further performing said planarization until at least said surface of said substrate is exposed, after said planarization in said third step.

19. An exposure apparatus that illuminates a mask with an energy beam, and sequentially transfers a pattern of said mask onto a plurality of shot areas on a sensitive substrate via a projection optical system, said exposure apparatus using said reference wafer for accuracy control according to Claim 1 to control overlay accuracy between said mask and said sensitive substrate.

20. The exposure apparatus according to Claim 19, wherein said control of said overlay accuracy includes at least one of controlling

an image forming characteristic including distortion of said projection optical system, and

a characteristic of an arrangement of a pattern image

of said mask which is sequentially transferred onto said substrate.

21. A device manufacturing method including a lithographic process, wherein exposure is performed using said exposure apparatus according to one of Claims 19 and 20 in said lithographic process.