

SPECIFICATION



EXPOSURE METHOD AND EXPOSURE SYSTEM

Technical Field

The present invention relates to an exposure method and exposure system (exposure apparatus) which are used to expose a mask pattern onto a sensitive substrate in a photolithography step for manufacturing a device, such as a semiconductor device, an image pickup device (CCD or the like), a liquid crystal display device or a thin film magnetic head.

Background Art

An exposure apparatus, such as a projection exposure apparatus (stepper or the like), which transfers the image of a pattern of a reticle serving as a mask onto each shot area on a wafer (or a glass plate or the like) where a resist serving as a sensitive material has been applied, via a projection optical system, is used in manufacturing semiconductor devices or the like. Because, for example, a semiconductor device is formed by overlaying several tens of layers of circuit patterns on a wafer in a predetermined positional relationship, those exposure apparatuses are equipped with an alignment unit, which comprises an alignment sensor for detecting the positions of alignment marks on a reticle (reticle marks) and alignment marks (wafer marks) provided in the individual shot areas on the wafer and a stage system for aligning the reticle with the wafer based on the result of the detection by this alignment sensor.

In addition, a reticle alignment microscope of an image processing type which illuminates a mark to be detected with illumination light of the same wavelength as that of exposure light is used as an alignment sensor for detecting a reticle mark. As an alignment sensor for detecting a wafer mark, an optical alignment sensor, such as a laser step alignment type, double-beam interference type, image processing type or the like, is used. When this alignment sensor for a wafer mark is used, it is necessary to have previously measured the distance between the center of the pattern image of a reticle



(exposure center) and the center of detection of this alignment sensor, i.e., the amount of the base line, with a high precision.

When the optical alignment sensor for detecting a wafer mark is used, a predetermined offset may remain in the detection result due to asymmetry or the like of the wafer mark to be detected. Such an offset is not very significant with respect to the overlaying precision that is required at present, and, more particularly, the offset in an image processing type sensor is slight. However, as the miniaturization of semiconductor devices or the like is improved further, the offset may cause problems. Japanese Patent Application, First Publication No. Hei 8-45814 has proposed a positioning method which detects the position of a wafer mark with a high precision without being affected by the asymmetry of the shape of the wafer mark by directly detecting the undulation of the surface of a resist which is produced by the wafer mark by using a scanning probe microscope (SPM) which performs relative scanning of the to-be-detected surface with a stylus or probe, such as an atomic force microscope.

As mentioned above, conventionally, a method has been proposed which uses a scanning probe microscope (SPM) for detecting the position of a wafer mark with a high precision. While the scanning probe microscope (SPM) has an excellent resolution, however, the time needed to detect the position of a wafer mark is longer than that for an optical alignment sensor, thus lowering the throughput of the exposure step. Further, as the probe moves substantially in contact with the surface of a resist, the durability drops, which requires frequent maintenance.

In a projection exposure apparatus which may involve alteration of the illumination conditions in accordance with the width of lines and the shape of a pattern to be exposed, the pattern of the image to be projected onto a wafer would slightly deviate from one illumination condition to another depending on the characteristics of the projection optical system. As the conventional reticle alignment microscope for detecting the position of a reticle mark is of the type which illuminates the to-be-detected mark with an illumination system different from the illumination optical system for the exposure light, however, a slight positional deviation is produced

between the center of the projected image of the pattern of the reticle and the center that is detected by the reticle alignment microscope every time the illumination condition for the exposure light is changed. This deviation may result in an overlaying error. One way to reduce this overlaying error is to perform, for example, test printing every time the illumination condition is changed, measure the overlaying error after development, and correct the alignment result by the overlaying error at the time of actually making exposure. However, this method is troublesome.

Accordingly, it is a first object of the present invention to provide an exposure method which can align a substrate to be exposed with a high precision even when the illumination condition is changed.

It is a second object of the present invention to provide an exposure method which can avoid reducing the throughput by decreasing the frequency of usage of a predetermined probe and maintain keep a high precision, when alignment is carried out by executing relative scanning with the probe.

It is a third object of the present invention to provide an exposure system which can use such exposure methods, and a method of manufacturing such an exposure system.

It is a further object of the present invention to provide a device which is manufactured with a high accuracy by using such exposure methods.

Disclosure of the Invention

A first exposure method according to the present invention for exposing a pattern (45) on a mask where a first positioning mark (RS1, RS2) is formed onto a substrate (W) where a second positioning mark (RM1-RM6) is formed on a non-shot area other than a shot area on which the pattern is to be transferred, comprises a first step of applying a sensitive material on the substrate; a second step of setting an illumination area on the mask in such a way as to illuminate substantially the first positioning mark alone; a third step of illuminating the mask to expose the first positioning mark onto the sensitive material on the non-shot area on the substrate; a

fourth step of detecting an undulation distribution of the sensitive material by performing relative scanning to a surface of the sensitive material with a predetermined probe; a fifth step of acquiring positional relation information of a latent image of the first positioning mark and the second positioning mark based on a result of the detection; a sixth step of performing alignment of the pattern with the substrate based on the positional relation information; and a seventh step of exposing the pattern onto the substrate after the alignment is completed.

According to the present invention, a box-in-box mark comprised of, for example, sub-scale marks (RS1, RS2) and recessed and protruding main-scale marks (RM1-RM6) or the like can be used as the first and second positioning marks.

According to the present invention, first, as one example, an optical alignment sensor for a mask and an optical alignment sensor for a substrate are used to acquire the amount of the base line of the alignment sensor for the substrate (the distance from the exposure center of the mask pattern to the detection center), then the alignment sensor for the substrate is used to detect the position of a predetermined positioning mark (base mark) on the substrate, and the detection result is corrected with the base line amount, so that the substrate is aligned with the mask pattern.

Next, in the case where exposure of the mask pattern with respect to one lot of substrates is actually started or in the case where the illumination condition is changed, the illumination area on the mask is set in such a way as to substantially illuminate the first positioning mark alone, thereby exposing the first positioning mark onto the sensitive material on the first substrate. As the undulation distribution of the surface of an ordinary sensitive material (e.g., an ordinary resist) is changed by the exposed latent image, the positional relation information (amount of positional deviation) of the second positioning mark (base mark) and the latent image of the first positioning mark on the substrate can be measured with a high precision by detecting the undulation distribution on the surface by relative scanning with the probe. From this amount of positional deviation, not only an illumination-condition induced offset of the alignment sensor for the mask but the offset of the base line amount of the alignment sensor for the substrate

is acquired. Further, a magnification error (scaling in a shot), a rotational error (rotation in a shot) between a predetermined pattern and the substrate or the like are also acquired by providing a plurality of positioning marks in a shot area. Thereafter, even when the illumination condition is changed, alignment can be carried out with a high precision by correcting the offset of the base line amount of the alignment sensor for the substrate and further correcting, if possible, the magnification error, the rotational error or the like, before a predetermined pattern is actually exposed. As a result, a high overlaying precision is obtained.

It is desirable that at least a latent image portion of the first positioning mark of the substrate should be heated between the third step and the fourth step.

When the second positioning mark is formed in a non-shot area on the substrate which is other than a shot area where the pattern is to be transferred, it is desirable that the first positioning mark should be exposed onto the sensitive material in the non-shot area in the third step.

The positional relation information is, for example, the amount of positional deviation between the latent image of the first positioning mark and the second positioning mark.

A second exposure method according to the present invention for exposing a pattern (45) on a mask where a first positioning mark (RS1, RS2) is formed onto a plurality of substrates on each of which a second positioning mark is formed, comprises a first step of applying a pressure-sensitive material on each of the plurality of substrates; a second step of exposing the first positioning mark onto the pressure-sensitive material on a first substrate in the plurality of substrates; a third step of detecting an undulation distribution of the pressure-sensitive material by performing relative scanning to a surface of the pressure-sensitive material on the first substrate with a predetermined probe; a fourth step of acquiring positional relation information of a latent image of the first positioning mark and the second positioning mark based on a result of the detection; a fifth step of performing alignment of a second substrate in the plurality of substrates which is different from the first substrate with the pattern based

on the positional relation information; and a sixth step of exposing the pattern onto the second substrate after the alignment is completed.

According to the second exposure method, after the positional relation information of the latent image of the first positioning mark and the second positioning mark on the first substrate is acquired, reduction in throughput can be limited and a high alignment precision is maintained by reducing the frequency of measurement using that probe by correcting the measured result (or the base line amount) with the offset obtained by the probe, using, for example, an optical alignment sensor for a substrate, with respect to the second and subsequent substrates, until the illumination condition is changed next time. In addition, the probe is worn out less.

It is desirable that an illumination area on the mask should be so set as to illuminate substantially the first positioning mark alone between the first step and the second step.

When the second positioning mark is formed in a non-shot area on the first substrate which is other than a shot area where the pattern is to be transferred, it is desirable that the first positioning mark should be exposed onto the sensitive material in the non-shot area in the second step.

A third exposure method according to the present invention for exposing a pattern (45) on a mask where a first positioning mark (RS1, RS2) is formed onto a predetermined substrate where a second positioning mark is formed, comprises a first step of applying a sensitive material on the predetermined substrate; a second step of exposing the pattern and the first positioning mark onto the sensitive material on the predetermined substrate; a third step of detecting an undulation distribution of the sensitive material by performing relative scanning to a surface of the sensitive material with a predetermined probe; and a fourth step of acquiring positional relation information of a latent image of the first positioning mark and the second positioning mark based on a result of the detection.

According to the third exposure method, the amount of the base line of, for example, an optical alignment sensor for a substrate should be acquired beforehand, and

alignment of the pattern with a predetermined substrate to be exposed is carried out using this alignment sensor. With respect to that predetermined substrate, the undulation distribution of the sensitive material based on a predetermined base pattern (e.g., the second positioning mark) and the latent image of a portion in the pattern which becomes the first positioning mark is detected in, for example, a predetermined shot area after exposure by relative scanning with the probe, so that the amount of positional deviation between the base pattern and the latent image can be detected with a high precision. Then, the offset by the illumination condition of the base line amount of the optical alignment sensor is acquired by this amount of positional deviation, and the magnification error or the rotational error or the like is further acquired depending on the structure of the pattern to be detected. That is, it is possible to evaluate the actual overlaying error of the image of that pattern.

It is desirable to further comprise a fifth step of changing the predetermined substrate to another substrate which is different from the predetermined substrate and on which the second positioning mark is formed; a sixth step of performing alignment of the another substrate with the pattern based on the positional relation information acquired in the fourth step; and a seventh step of exposing the pattern onto the another substrate after the alignment is completed. In this case, with regard to the substrates including and following the other substrate, a reduction in the throughput is limited to acquire a high alignment precision by correcting the base line amount of the optical alignment sensor and also correcting the magnification error or the like if possible.

It is desirable that when the second positioning mark is formed in a shot area on the predetermined substrate in which at least the pattern is to be transferred, the first positioning mark should be exposed onto the sensitive material in the shot area in the second step.

It is desirable to expose the pattern onto each of a plurality of shot areas on the predetermined substrate in the second step, and to select an arbitrary one of the plurality of shot areas and detect the latent image of the first positioning mark in the selected shot area and the second positioning mark by performing relative scanning with the probe in

the third step.

A fourth exposure method according to the present invention for exposing a pattern (45) on a mask where a first positioning mark (RS1, RS2) is formed onto a substrate where a second positioning mark is formed, comprises a first step of applying a sensitive material on the substrate; a second step of exposing the first positioning mark onto the sensitive material on the substrate; a third step of heating at least a latent image portion of the first positioning mark on the substrate; and a fourth step of detecting an undulation distribution of the sensitive material after the third step.

According to the fourth exposure method, before the undulation of the sensitive material is detected using the predetermined probe, the to-be-detected area (the latent image portion of the first positioning mark) is partially heated. When a chemical amplification type resist is used as that sensitive material, an undulation is not produced on its surface depending on the exposure-induced latent image, so that the to-be-detected area of the sensitive material is heated in a spot using, for example, laser light or the like to perform a sort of post-exposure bake (PEB), thus producing an undulation on the exposed latent image portion. This makes it possible to detect the position of the latent image using the probe. The use of laser light or the like serving as a heating light beam having a wavelength range which has a low sensitivity to the sensitive material can reduce the influence on the pattern that is obtained after development.

It is desirable that an illumination area on the mask should be so set as to illuminate substantially the first positioning mark alone between the first step and the second step.

It is desirable that when the second positioning mark is formed in a shot area on the substrate in which at least the pattern is to be transferred, and the pattern and the first positioning mark should be exposed onto the sensitive material in the shot area in the second step.

It is desirable that when the second positioning mark is formed in a shot area on the substrate in which at least the pattern is to be transferred, the pattern and the first positioning mark should be exposed onto the sensitive material in the shot area in the

second step.

It is desirable to further comprise a fifth step of acquiring positional relation information of a latent image of the first positioning mark and the second positioning mark based on a result of the detection; a sixth step of performing alignment of the substrate with the pattern based on the positional relation information; and a seventh step of exposing the pattern onto the substrate after the alignment is completed.

Alternatively, it is desirable to further comprise a fifth step of acquiring positional relation information of a latent image of the first positioning mark and the second positioning mark based on a result of the detection; a sixth step of changing the substrate to another substrate which is different from the substrate and on which the second positioning mark is formed; a seventh step of performing alignment of the other substrate with the pattern based on the positional relation information acquired in the fifth step; and an eighth step of exposing the pattern onto the another substrate after the alignment is completed.

Further, it is desirable to expose the pattern onto each of a plurality of shot areas on the substrate in the second step, and to select an arbitrary one of the plurality of shot areas and detect the latent image of the first positioning mark in the selected shot area and the second positioning mark by performing relative scanning with the probe in the fourth step.

According to the above-described exposure method, one example of the predetermined probe is the probe of an atomic force microscope. Other probes, such as the probe of a scanning probe microscope (SPM), can also be used.

A first exposure system according to the present invention for exposing a pattern on a mask where a first positioning mark is formed onto a substrate where a second positioning mark is formed on a non-shot area other than a shot area on which the pattern is to be transferred and where a sensitive material is applied, comprises an exposure apparatus having a light source for illuminating the mask with illumination light and an illumination area setting section, arranged between the light source and the mask, for setting an illumination area on the mask in such a way as to illuminate

substantially the first positioning mark alone; a detecting unit for acquiring positional relation information of a latent image of the first positioning mark, exposed onto the non-shot area on the substrate, and the second positioning mark by performing relative scanning to a surface of the sensitive material with a predetermined probe; and an alignment unit, electrically connected to the detecting unit, for performing alignment of the pattern with the substrate based on the positional relation information.

According to this first exposure system, the base line amount of an alignment sensor for a substrate should be measured beforehand by using an alignment sensor a mask as one example. Then, the base line amount is corrected by using the result of the detecting unit, thus allowing the first exposure method of the present invention to be used.

It is desirable to comprise a substrate transfer line arranged between the exposure apparatus and the detecting unit as a passage for transferring the substrate on which the first positioning mark is exposed by the exposure apparatus to the detecting unit. It is preferable to comprise a heating unit, disposed on the substrate transfer line between the exposure apparatus and the detecting unit, for heating at least a latent image portion of the first positioning mark of the substrate.

Additionally, it is desirable that the exposure apparatus should have a projection system for projecting the pattern onto the substrate; and the detecting unit should be located in the vicinity of the projection system in the exposure apparatus. In addition, it is preferable to further comprise a heating unit, disposed in the exposure apparatus, for heating at least a latent image portion of the first positioning mark of the substrate.

When the second positioning mark is formed in a non-shot area on the substrate which is other than a shot area where the pattern is to be transferred, it is desirable that the exposure apparatus should expose the first positioning mark onto the sensitive material in the non-shot area in the third step.

A first predetermined device according to the present invention is manufactured by transferring and exposing the pattern onto the substrate by the first exposure system of the present invention. As the present invention provides a high overlaying precision,

a high-precision device is obtained.

A second exposure system according to the present invention for exposing a pattern on a mask where a first positioning mark is formed onto each of a plurality of substrates on each of which a second positioning mark is formed and a sensitive material is applied, comprises an exposure apparatus for exposing the first positioning mark onto the sensitive material on a first substrate in the plurality of substrates; a detecting unit for detecting an undulation distribution of the sensitive material, provided by a latent image of the first positioning mark and the second positioning mark, by performing relative scanning to a surface of the sensitive material on the first substrate with a predetermined probe, and acquiring positional relation information of a latent image of the first positioning mark and the second positioning mark based on a result of the detection; and an alignment unit, electrically connected to the detecting unit, for performing alignment of a second substrate different from the first substrate with the pattern based on the positional relation information, wherein the pattern is exposed onto the second substrate after the alignment is completed. This second exposure system of the present invention can use the second exposure method of the present invention. Further, the throughput of the exposure apparatus does not drop at all.

A second predetermined device according to the present invention is manufactured by transferring and exposing the pattern onto a plurality of substrates by the second exposure system of the present invention. As the present invention can also provide a high overlaying precision, a high-precision device is obtained also.

A third exposure system according to the present invention for exposing a pattern on a mask where a first positioning mark is formed onto a predetermined substrate on which a second positioning mark is formed and a sensitive material is applied, comprises an exposure apparatus for exposing the first positioning mark onto the sensitive material on the predetermined substrate; and a detecting unit for detecting an undulation distribution of the sensitive material, provided by a latent image of the first positioning mark and the second positioning mark, by performing relative scanning to a surface of the sensitive material with a predetermined probe, and acquiring

positional relation information of a latent image of the first positioning mark and the second positioning mark based on a result of the detection. This third exposure system of the present invention can use the second exposure method of the present invention. Further, the throughput of the exposure apparatus does not drop at all.

It is desirable to comprise an alignment unit, electrically connected to the detecting unit, for performing alignment of another substrate which is different from the predetermined substrate and on which the second positioning mark is formed with the pattern based on the positional relation information, and that the exposure apparatus should expose the pattern onto the another substrate after the alignment is completed.

It is desirable that when the second positioning mark is formed in a shot area on the predetermined substrate in which at least the pattern is to be transferred, the exposure apparatus should expose the first positioning mark onto the sensitive material in the shot area.

A third predetermined device according to the present invention is manufactured by transferring and exposing the pattern onto the substrate by the third exposure system of the present invention. As the present invention can also provide a high overlaying precision, a high-precision device is obtained also.

Next, a fourth exposure system according to the present invention for exposing a pattern on a mask where a first positioning mark is formed onto a substrate on which a second positioning mark is formed and a sensitive material is applied, comprises an exposure apparatus for exposing the first positioning mark onto the sensitive material on the substrate; a heating unit for heating a portion of the substrate where at least the first positioning mark is exposed; and a detecting unit for detecting an undulation distribution of the sensitive material, provided by the latent image of the first positioning mark and the second positioning mark, by performing relative scanning with a predetermined probe, and acquiring positional relation information of a latent image of the first positioning mark and the second positioning mark based on a result of the detection. This fourth exposure system of the present invention can use the fourth exposure method of the present invention.

It is preferable that when a substrate transfer line arranged between the exposure apparatus and the detecting unit as a passage for transferring the substrate on which the first positioning mark is exposed by the exposure apparatus to the detecting unit, a heating unit should be disposed on the substrate transfer line between the exposure apparatus and the detecting unit. It is further preferable that the heating unit should include a baking unit for baking the sensitive material.

It is preferable that when the exposure apparatus has a projection system for projecting the pattern onto the substrate and the detecting unit is located in the vicinity of the projection system in the exposure apparatus, the heating unit should be disposed in the exposure apparatus. It is also preferable that the heating unit should include a laser device for irradiating a laser beam onto the substrate.

It is desirable that the exposure apparatus should be able to expose the pattern onto each of a plurality of shot areas on the substrate and the detecting unit should select an arbitrary one of the plurality of shot areas and detect the latent image of the first positioning mark in the selected shot area and the second positioning mark by performing relative scanning with the probe.

A fourth predetermined device according to the present invention is manufactured by transferring and exposing the pattern onto the substrate. As the present invention provides a high overlaying precision too, a high-precision device is also obtained.

A first exposure system manufacturing method according to the present invention for manufacturing an exposure system for exposing a pattern on a mask where a first positioning mark is formed onto a substrate where a second positioning mark is formed and where a sensitive material is applied, manufactures the exposure system by assembling a light source for illuminating the mask with illumination light; an illumination area setting section, arranged between the light source and the mask, for setting an illumination area on the mask in such a way as to illuminate substantially the first positioning mark alone; a detecting section for detecting an undulation distribution, provided by a latent image of the first positioning mark, exposed on the non-shot area

on the substrate, and the second positioning mark, by performing relative scanning to a surface of the sensitive material with a predetermined probe, and acquiring positional relation information of the latent image of the first positioning mark and the second positioning mark based on a result of the detection; and an alignment section, electrically connected to the detecting section, for performing alignment of the pattern with the substrate based on the positional relation information, in a predetermined positional relationship.

Next, a second exposure system manufacturing method according to the present invention for manufacturing an exposure system for exposing a pattern on a mask where a first positioning mark is formed onto each of a plurality of substrates on each of which a second positioning mark is formed and a sensitive material is applied, manufactures the exposure system by assembling an exposure section for exposing the first positioning mark onto the sensitive material on a first substrate in the plurality of substrates; a detecting section for detecting an undulation distribution of the sensitive material, provided by a latent image of the first positioning mark and the second positioning mark, by performing relative scanning to a surface of the sensitive material on the first substrate with a predetermined probe, and acquiring positional relation information of a latent image of the first positioning mark and the second positioning mark based on a result of the detection; and an alignment section, electrically connected to the detecting section, for performing alignment of a second substrate in the plurality of substrates, which is different from the first substrate, with the pattern based on the positional relation information, before the exposure section exposes the pattern onto the second substrate, in a predetermined positional relationship.

A third exposure system manufacturing method according to the present invention for manufacturing an exposure system for exposing a pattern on a mask where a first positioning mark is formed onto a predetermined substrate on which a second positioning mark is formed and a sensitive material is applied, manufactures the exposure system by assembling an exposure section for exposing the first positioning mark and the pattern onto the sensitive material on the predetermined substrate; and a

detecting section for detecting an undulation distribution, provided by a latent image of the first positioning mark and the second positioning mark, by performing relative scanning to a surface of the sensitive material on the predetermined substrate with a predetermined probe, and acquiring positional relation information of a latent image of the first positioning mark and the second positioning mark based on a result of the detection, in a predetermined positional relationship.

Further, a fourth exposure system manufacturing method according to the present invention for manufacturing an exposure system for exposing a pattern on a mask where a first positioning mark is formed onto a substrate on which a second positioning mark is formed and a sensitive material is applied, manufactures the exposure system by assembling an exposure section for exposing the first positioning mark onto the sensitive material on the substrate; a heating section for heating a portion of the substrate where at least the first positioning mark is exposed; and a detecting section for detecting an undulation distribution, provided by the latent image of the first positioning mark and the second positioning mark, by performing relative scanning to a surface of the sensitive material with a predetermined probe, and acquiring positional relation information of a latent image of the first positioning mark and the second positioning mark based on a result of the detection, in a predetermined positional relationship.

Brief Description of the Drawings

FIG. 1 is a structural diagram illustrating a projection exposure apparatus according to a first embodiment of the present invention.

FIG. 2 is a perspective view showing the layout of a stage system, an alignment sensor and so forth in the case of measuring the base line according to the first embodiment.

FIG. 3 is a structural diagram illustrating a laser illumination system according to the first embodiment.

FIG. 4 is a plan view showing the pattern structure of a reticle R in FIG. 1.

FIG. 5 is a plan view showing a shot layout on a wafer W which is an exposure target in FIG. 1.

FIG. 6A is an enlarged plan view showing main-scale and sub-scale images for measuring registration.

FIG. 6B is a cross-sectional view along the line AA in FIG. 6A.

FIG. 6C is a diagram showing one example of a detection signal obtained by performing relative scanning to the surface of a resist in FIG. 6B with a probe.

FIG. 7 is a structural diagram illustrating a part of an exposure system according to a second embodiment of the present invention.

Best Mode for Carrying Out the Invention

Preferred embodiments of the present invention will be described below. To begin with, the first embodiment of the present invention will be described with reference to FIGS. 1 to 6.

FIG. 1 illustrates the schematic structure of a projection exposure apparatus which is used in this embodiment. In this FIG. 1, an exposure light IL of an ultraviolet pulse laser beam from an ArF excimer laser source 1 whose band is narrowed with a wavelength of 193 nm passes a beam matching unit (MBU) 3 including a movable mirror, etc., and enters a variable light reducing unit 6 via a light-shielding pipe 5. An exposure controller 29, which controls the light exposure with respect to a resist on a wafer, controls the initiation and stopping or the like of light emission of the ArF excimer laser source 1, and adjusts the light reducing ratio of the variable light reducing unit 6. The exposure controller 29 receives information, such as a target amount of light exposure, from a main control system 28 which performs the general control of the operation of the entire apparatus and outputs information, such as the amount of light exposure to be actually measured, to the main control system 28, as will be discussed below. Note that other excimer laser beams, such as a KrF (wavelength of 248 nm) or an F₂ (wavelength of 157 nm) excimer laser, i rays (wavelength of 365 nm) of a mercury lamp, or soft X rays or the like can be used as the exposure light.

The exposure light IL that has passed the variable light reducing unit 6 enters a fly-eye lens 8 through a beam shaping optical system comprising lens systems 7A and 7B. An aperture stop plate 9 of an illumination system is disposed on the light emerging surface of the fly-eye lens 8 in a rotatable manner by a drive motor 10. Arranged on the aperture stop plate 9 are a circular aperture stop 9a for normal illumination, an aperture stop 9b for annular band illumination, an aperture stop 9c for modified illumination that is comprised of a plurality of small eccentric openings, and so forth. As the main control system 28 turns the aperture stop plate 9 via the drive motor 10 in accordance with the illumination condition, a predetermined aperture stop which defines the illumination condition is set on the light emerging surface of the fly-eye lens 8.

The exposure light IL that has emerged from the fly-eye lens 8 and has passed the predetermined aperture stop in the aperture stop plate 9 enters a beam splitter 11 that has a high light transmittance and low reflectance. The exposure light that is reflected by the beam splitter 11 enters an integrator sensor 12 which is comprised of a photoelectric sensor and whose detection signal is supplied to an exposure controller 29. Based on the detection signal from the integrator sensor 12, the exposure controller 29 indirectly monitors the illuminance (pulse energy) of the exposure light IL with respect to the wafer and its integrated value (amount of light exposure).

The exposure light IL that has passed the beam splitter 11 enters a fixed field stop 15 in a reticle blind mechanism 16 through a reflection mirror 13 and a condenser lens system 14. When the projection exposure apparatus of this embodiment is a scanning exposure type like a step and scan system, a movable field stop for preventing exposure to unnecessary areas before and after scanning exposure is provided in addition to the field stop 15 that defines an illumination area. The exposure light IL that has been shaped by the field stop 15 of the reticle blind mechanism 16 irradiates, with a uniform illumination distribution, an illumination area conjugate with, for example, the rectangular opening of the field stop 15 on a circuit pattern area of a reticle R via an image-forming lens system 17, a reflection mirror 18 and a main condenser lens system

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Under the exposure light IL, the image of the circuit pattern in the illumination area of the reticle R is transferred to an exposure area of a resist layer on a wafer W placed on the image forming surface of a projection optical system PL telecentric to both sides (or one side to the wafer side) at a predetermined projection magnification β (β being, for example, 1/4, 1/5 or the like) via the projection optical system PL. The exposure area is positioned on one of a plurality of shot areas on the wafer W. A chemically amplified-type resist is used as the resist that is applied on the wafer W in this embodiment. While the projection optical system PL in this embodiment is a dioptric system (refraction system), a catadioptric system (catarefraction system) may be used to reduce absorption to short-wavelength exposure light.

As the ArF excimer laser source 1 is used in this embodiment, a sub chamber 60 is provided to shield the individual illumination light paths from the inside of the pipe 5 to the variable light reducing unit 6, to the lens systems 7A and 7B, and further to the fly-eye lens 8 to the main condenser lens system 19 from the outside air. To avoid absorption of the exposure light by oxygen, dry nitrogen gas or helium gas is supplied into the entire sub chamber 60 and the entire space (the space between a plurality of lens elements) in the mirror barrel of the projection optical system PL.

A description will now be given with the Z axis taken in parallel to the optical axis AX of the projection optical system PL, the X axis taken in parallel to the sheet surface of FIG. 1 in a plane perpendicular to the Z axis, and the Y axis taken perpendicular to the sheet surface of FIG. 1. At this time, the reticle R is chucked on a reticle stage 20, which is mounted on a reticle base 21 in such a way as to be movable in the X direction, the Y direction and the rotational direction.

As shown in FIG. 2, a movable mirror 22a, which has two reflection surfaces approximately perpendicular to the X axis and the Y axis, is fixed onto the reticle stage 20 and a laser beam LRX parallel to the X axis, and biaxial laser beams LRY1 and LRY2 parallel to the Y axis are irradiated on this movable mirror 22a by a laser interferometer in a drive control unit 22 in FIG. 1. This laser interferometer measures

the X coordinate, the Y coordinate and the rotational angle of the reticle stage 20 (reticle R) in real time. The drive control unit 22 controls the positioning operation of the reticle stage 20 via an unillustrated drive motor (a linear motor, voice coil motor or the like) based on the measuring results and control information from the main control system 28.

In FIG. 1, the wafer W is chucked on a sample table 24 via a wafer holder 23. The sample table 24 is secured onto an XY stage 25 which moves two-dimensionally along the XY plane parallel to the image of the projection optical system PL, and a wafer stage 26 comprises the sample table 24 and the XY stage 25. The sample table 24 controls the focus position (position in the Z direction) of the wafer W and the tilt angle thereof to fit the surface of the wafer W into the image of the projection optical system PL by an auto-focus system and auto leveling system, and the XY stage 25 performs stepping of the wafer W in the X direction and the Y direction. An alignment sensor 35 for a wafer mark of an off-axis system and image processing system is located on the negative X-directional side of the projection optical system PL projection optical system PL.

Further, the negative X-directional side and the positive Y-directional side of the sample table 24 are both mirror-finished and used as a movable mirror. As shown in FIG. 2, a laser interferometer in a drive control unit 27 irradiates a laser beam LWX onto the negative X-directional side of the sample table 24 in parallel to the X axis, irradiates biaxial laser beams LWY1 and LWY2 onto the positive Y-directional side of the sample table 24 in parallel to the Y axis. In this case, the extension line of the optical axis of the laser beam LWX of the X axis passes the detection center of the alignment sensor 35 and the optical axis AX of the projection optical system PL, the extension line of the optical axis of one laser beam LWY1 of the Y axis passes the optical axis AX, and the extension line of the optical axis of the other laser beam LWY2 of the Y axis passes the detection center of the alignment sensor 35. Accordingly, the X coordinate of the sample table 24 is measured by the laser beam LWX, and the Y coordinate of the sample table 24 is measured by the laser beam LWY1 at the time of

light exposure and is measured by the laser beam LWY2 at the time of alignment. The rotational angle of the sample table 24 is measured from the difference between the values measured by the two laser beams LWY1 and LWY2. Selective use of the laser beams LWY1 and LWY2 that way prevent an Abbe error.

When the sides of the sample table 24 are used as a moving mirror as shown in FIG. 2, a positional deviation in the Z direction occurs between the optical path of the laser beam and the surface of the wafer W, an Abbe error may be produced by pitching or rolling of the sample table 24. To avoid it, laser beams may be irradiated onto the sides of the sample table 24 at a predetermined distance apart from each other in the Z direction with respect to the laser beams LWY1 and LWY2, so that an Abbe error caused by pitching of the sample table 24 or the like is corrected based on values measured by a pair of laser beams apart from each other in the Z direction. Further, a moving mirror having perpendicular reflection surfaces may be provided on the sample table 24, as on the reticle stage 20, and the position of the sample table 24 may be measured by irradiating a laser beam on this moving mirror.

Returning to FIG. 1, the measured values of the two-dimensional position and rotational angle of the sample table 24 (wafer W) that are measured by the laser interferometer in the drive control unit 27 are also supplied to the main control system 28 and an alignment controller 36. And, the drive control unit 27 controls the positioning operation of the XY stage 25 via the unillustrated drive motor (linear motor or the like) based on the measured values and control information from the main control system 28. It is to be noted that the rotational error of the wafer W is corrected by rotating the reticle stage 20 via the main control system 28 and the drive control unit 22 as one example.

At the time of light exposure, the illumination condition is set as the main control system 28 rotates the aperture stop plate 9 as needed. And, the operation of moving a next shot area on the wafer W to the exposure area by the projection optical system PL via the XY stage 25 after exposure of the pattern image of the reticle R onto one shot area on the wafer W is completed, then exposing the pattern image of the

reticle R is repeated in the step and repeat system. At this time, the exposure controller 29 controls the amount of light exposure with respect to each shot area on the wafer W.

In the case where the projection exposure apparatus of this embodiment is of a scanning exposure type like the step and scan system, the wafer W is scanned in the negative X direction (or positive X direction) at a speed $\beta \cdot V_r$ (β being the projection magnification with respect to the exposure area by the projection optical system PL via the XY stage 25 in synchronism with the reticle R being scanned in the positive X direction (or negative X direction) at a speed V_r with respect to the illumination area of the exposure light IL via the reticle stage 20.

Before such exposure to each shot area on the wafer W is carried out, it is necessary to align the pattern of the reticle R with each shot area on the wafer W beforehand. For this purpose, a pair of, for example, cross-shaped reticle marks 37A and 37B (see FIG. 2) are so formed as to sandwich the pattern area of the reticle R in the Y direction, and reticle alignment microscopes (hereinafter called "RA microscopes") 38A and 38B of an image processing type are respectively arranged above the reticle marks 37A and 37B. The RA microscopes 38A and 38B each have a downward illumination system for irradiating illumination light of the same wavelength range as that of the exposure light IL and a two-dimensional image pickup device, such as CCD, whose image pickup surface is located at a position conjugate with the pattern surface of the reticle R. Image pickup signals from those image pickup devices are supplied to the alignment controller 36. The alignment controller 36 processes the image pickup signals to detect, for example, the amounts of positional deviation of the images of the two marks in the X direction and the Y direction and sends the detection results to the main control system 28.

As shown in FIG. 2, a reference member 32 is secured onto the sample table 24 in the vicinity of the wafer holder 23, and two frame-like two-dimensional reference marks 34A and 34B and a two-dimensional reference mark 33 which is a combination of a line and space pattern in the X direction and a line and space pattern in the Y direction are formed on the reference member 32. The distance between the reference

marks 34A and 34B is set equal to the designed distance between the projected images of the reticle marks 37A and 37B on the wafer stage side, and the distance between the center of the reference mark 34A, 34B and the center of the reference mark 33 is set to a designed distance (base line amount) BL1 between the center of the pattern image of the reticle R and the detection center of the alignment sensor 35. The alignment sensor 35 has a downward illumination system, which illuminates a to-be-detected mark with illumination light which is of a relatively broad band and non-sensitive to the resist on the wafer W, an index mark located on the surface where the image of the to-be-detected is to be formed, and a two-dimensional image pickup device which picks up the images of the to-be-detected mark and the index mark. The image pickup signal of this image pickup device is also supplied to the alignment controller 36. The alignment controller 36 processes the image pickup signal to detect the amounts of positional deviation of the image of the to-be-detected mark in the X direction and the Y direction with respect to the center (detection center) of the index mark and sends the detection results to the main control system 28.

Returning to FIG. 1, an atomic force microscope 39 having a probe 40 is arranged on the positive X-directional side of the projection optical system PL. The atomic force microscope 39 can displace the probe 40 in the Z direction within a predetermined short moving stroke. In this case, the atomic force microscope 39 moves the probe 40 close to the to-be-detected object (the resist on the wafer W in this embodiment) at such a minute distance as to generate repulsive force between the atoms at the distal end of the probe 40 and the atoms (or molecules) of the to-be-detected object, controls the Z-directional position of the probe 40 so as to make the repulsive force constant, produces a detection signal according to the X-directional position of the probe 40 in the moving stroke and sends the detection signal to the alignment controller 36.

In the case of using the probe 40, with the Z-directional position of the probe 40 controlled in such a way that the repulsive force between the distal end of the probe 40 and the surface of the resist on the wafer W becomes constant, the wafer W is moved in

the X direction and the Y direction via the XY stage 25. Accordingly, the probe 40 displaces in the Z direction in responsive to even a very small recess or protrusion on the surface of the resist on the wafer W. Therefore, as the alignment controller 36 fetches the detection signal indicating the Z-directional displacement of the probe 40 in association with the X coordinate and Y coordinate of the sample table 24, the undulation distribution of the surface of the resist on the wafer W can be measured. Further, the alignment controller 36 processes the undulation distribution by, for example, the slice level scheme or pattern matching scheme, to detect the positions of the base mark of the resist and the latent image of a predetermined mark in the resist, acquires the amounts of positional deviation between those marks in the X direction and the Y direction and supplies them to the main control system 28. The more detailed detection principle or the like of an atomic force microscope is disclosed in, for example, Japanese Patent Application, First Publication No. Hei 8-45814.

The projection exposure apparatus of this embodiment is equipped with a laser illumination system as a heating system for partially heating the resist on the wafer W after exposure and before development. The heating may be considered as a sort of PEB (Post-Exposure Bake).

FIG. 3 illustrates the laser illumination system. In FIG. 3, at the time of heating a portion on the wafer W, a laser beam LB1 which is emitted from a laser light source 41 and has a wavelength range (infrared range in this embodiment) of a low sensitivity to the resist on the wafer W, forms a spot beam on the resist on the wafer W via a modulation element 42 having an electro-optical element or the like, a mirror 43, and a condenser lens 44 located on a side of the projection optical system PL. The size of the spot beam is set large enough to cover the exposed mark image to be detected, e.g., the image of a mark for registration measurement. The modulation element 42 is an intensity modulation element that is a combination of a Pockels cell, a polarizer, and an analyzer as one example. The oscillation timing of the laser light source 41 and the operation of the modulation element 42 are controlled by the main control system 28.

In this case, the distances between the detection center of the alignment sensor

35 and the focus position of the laser beam LB1 set by the condenser lens 44 in the X direction and the Y direction have been obtained beforehand and stored in a memory section in the main control system 28. After moving a to-be-heated area on the wafer W to the focus position set by the condenser lens 44 via the XY stage 25, the main control system 28 executes the oscillation of the laser light source 41 or modulation of the modulation element 42 to irradiate the laser beam LB1 on that area for a predetermined time. The irradiation of the laser beam LB1 partially heats up the resist on the wafer W to several tens of °C, for example, about 80°C to 90°C. To reduce the influence of heat generation of the laser light source 41, the laser light source 41 may be provided outside the chamber where the projection exposure apparatus of this embodiment is placed so that the laser beam from the laser light source 41 is guided to a side of the projection optical system PL via an optical fiber or the like.

A detailed description will now be given of one example of the alignment operation in the projection exposure apparatus of this embodiment.

First, a mark for registration (amount of relative positional deviation) measurement is formed on the reticle R. Through the process up to this point, the mark for registration measurement has been formed on the wafer W in addition to the circuit patterns and wafer marks in the individual shot areas, and information on the shot layout on the wafer W and the layout coordinates of the individual marks has been supplied as exposure data to the main control system 28.

FIG. 4 is a plan view showing the reticle R in FIG. 1, and a predetermined master pattern is formed on a pattern area 45 of the reticle R in FIG. 4. A frame-like light shielding band 46 is so formed as to enclose the pattern area 45, a pair of reticle marks 37A and 37B are formed in such a way as to sandwich the light shielding band 46 in the Y direction and a pair of sub-scales RS1 and RS2 for registration measurement, each of which is comprised of a rectangular opening pattern, are formed in the positive X-directional side of the light shielding band 46 at a predetermined distance in the Y direction. A pair of marks, like the sub-scales RS1 and RS2, are also formed on a part of the master pattern in the pattern area 45.

FIG. 5 is a plan view showing the wafer W to be exposed, and the surface of the wafer W is segmented into shot areas SA1, SA2, ..., SAN (N being an integer equal to or greater than 3, for example) in the X direction and the Y direction, and circuit patterns and two-dimensional wafer marks WM1 to WM4, which are comprised of four protrusions (or recesses) of, for example, a cross shape, are formed in each of the shot areas SA1-SAN in FIG. 5. A pair of two-dimensional main scales RMA and RMB each comprised of a rectangular recess (or protrusion) for registration measurement are also formed in each of the shot areas SA1-SAN. Further, a pair of first two-dimensional main scales RM1 and RM2, a pair of second two-dimensional main scales RM3 and RM4 and a pair of third two-dimensional main scales RM5 and RM6, each comprised of a rectangular recess (or protrusion) for registration measurement are formed on the wafer W at three locations in the vicinity of the shot areas. A resist is so applied as to cover those shot areas SA1-SAN and the marks for registration measurement.

To implement alignment in this embodiment, first, the reticle alignment and measuring the base line amount of the alignment sensor 35 for the wafer mark are carried out. To accomplish this, as shown in FIG. 2, the XY stage 25 is driven to move the reference marks 34A and 34B of the reference member 32 on the sample table 24 to positions approximately conjugate with the reticle marks 37A and 37B. Under this state, exposure light IL is irradiated by the downward illumination system of the RA microscope 38A to pick up the overlaid images of the reference mark 34A and the reticle mark 37A, so that the alignment controller 36 detects the amounts of positional deviation ($\Delta RX1$, $\Delta RY1$) of the reticle mark 37A in the X direction and the Y direction with respect to the image of the reference mark 34A. In addition, the amounts of positional deviation ($\Delta RX2$, $\Delta RY2$) of the reticle mark 37B with respect to the reference mark 34B is detected via the RA microscope 38B and those amounts of positional deviation are supplied to the main control system 28 in FIG. 1.

The main control system 28 moves the reticle stage 20 in such a manner that the amounts of positional deviation $\Delta RX1$ and $\Delta RY1$ in the X direction become 0, and the amounts of positional deviation in the Y direction are distributed ($\Delta RY1 = \Delta RY2$).

This completes the reticle alignment. The reason why the amounts of positional deviation in the Y direction are not set to 0 is that a magnification error cannot be corrected easily. It is however desirable to set the amounts of positional deviation in the Y direction to 0 by, for example, controlling the projection magnification of the projection optical system PL or moving the reticle R up and down if possible.

With the reticle alignment completed in this manner, the alignment sensor 35 detects the amounts of positional deviation in the X direction and the Y direction from the detection center of the reference mark 33 in FIG. 2. The amounts of positional deviation are also supplied to the main control system 28, which corrects the known distance BL1 between the center of the reference mark 34A, 34B and the center of the reference mark 33 with the amounts of positional deviation, thereby obtaining the base line amount BL (vector amount) of the alignment sensor 35, and stores the base line amount.

Next, considering the wafer W on the wafer holder 23 as the top wafer in, for example, one lot of wafers, alignment of each shot area of the wafer W is carried out using the alignment sensor 35. To accomplish this, n (n being an integer equal to or greater than, for example, 4) wafer marks are selected from four wafer marks WM1 to WM4 of each of the shot areas SA1-SAN on the wafer W in FIG. 5, and the amounts of positional deviation from the detection centers of those wafer marks are detected via the alignment sensor 3. It is desirable that of the n wafer marks, at least two wafer marks should lie at different positions in one shot area.

The main control system 28 acquires the layout coordinates of the n wafer marks by adding the X coordinate and Y coordinate of the sample table 24 at the time of detecting the positions of the associated wafer marks to those amounts of positional deviation. Based on the actually measured layout coordinates and the corresponding designed layout coordinates, the main control system 28 computes the X-directional and Y-directional scalings of the wafer W (wafer scalings), the rotation of the shot layout of the wafer W (wafer rotation), the degree of orthogonality of the shot layout (wafer orthogonal degree), the X-directional and Y-directional offsets of the wafer W, the

magnification error of each shot area of the wafer W (intra-shot scaling) and the rotational error of each shot area (intra-shot rotation) or the like in a so-called enhanced global alignment (EGA) of multiple points in a shot. This computation is called an "EGA computation". Using those parameters, the main control system 28 computes the layout coordinates of the individual shot areas SA1-SAN on the wafer W and the layout coordinates of the main scales RM1-RM6 for registration measurement on the coordinate system that defines the moving position of the sample table 24. This completes the wafer alignment. Thereafter, the projection magnification of the projection optical system PL or the Z-directional position of the reticle R is corrected in accordance with the intra-shot scaling, if possible, to thereby correct the rotational angle of the reticle R in accordance with the intra-shot rotation.

Next, based on the coordinates that are obtained by correcting the layout coordinates of the main scales RM1-RM6 for registration measurement computed in the above manner with the base line amount of the alignment sensor 35, the pair of main scales RM1 and RM2 on the wafer W are moved to the positions conjugate with the sub-scales RS1 and RS2 on the reticle R in FIG. 4, the illumination area is set by the field stop 15 in FIG. 1 in such a way as to enclose the sub-scales RS1 and RS2 alone, and onto the resist layers on the main scales RM1 and RM2 are exposed to the images of the sub-scales RS1 and RS2. Likewise, the resist layers on the pair of main scales RM3 and RM4 and the pair of main scales RM5 and RM6 are exposed to images of the sub-scales RS1 and RS2 are sequentially.

As the resist in this embodiment is a chemically amplified-type resist, the undulation on the surface of the resist is not changed by the exposed latent image alone. To make the exposed latent images of the sub-scales RS1 and RS2 for registration measurement the undulation distribution on the surface of the resist, therefore, areas on the resist on the wafer W where the images of the sub-scales RS1 and RS2 have been exposed are partially heated by the laser illumination system in FIG. 3. To accomplish this, the centers of the main scales RM1-RM6 on the wafer W (the designed centers) should be sequentially moved to the focus position of the laser beam by the condenser

lens 44 of the laser illumination system in FIG. 3 to irradiate the laser beam spot on the resist layer at the focus position.

If the resist in this embodiment is not a chemically amplification type resist, partial heating should not necessarily be carried out before detecting the latent image.

Next, the amounts of positional deviation between the main scales RM1, RM2 to RM5, RM6 on the wafer W and the images (latent images) of the sub-scales RS1 and RS2 to which the resist layer lying on the main scales has been exposed are measured using the atomic force microscope 39 in FIG. 1. To measure the amount of positional deviation between the main scale RM1 and the image of the sub-scale RS1, for example, the area on the wafer W, where the main scale RM1 is formed (the designed area), is moved to the bottom portion of the probe 40 of the atomic force microscope 39 in FIG. 1, the atomic force microscope 39 is activated, and the sample table 24 is moved in the X direction and the Y direction in a stroke wider by some degree than the width of the main scale RM1 via the XY stage 25, and a detection signal DS corresponding to the Z-directional position of the probe 40 is fetched together with the coordinates of the sample table 24 to the alignment controller 36.

FIG. 6A is an enlarged plan view showing the main-scale RM1 and the image RS1W of the sub-scale RM1, and FIG. 6B is a cross-sectional view along the line AA in FIG. 6A. As shown in FIG. 6B, a resist 47 is applied onto the wafer W and only a step 47a corresponding to the main scale RM1 comprised of a recess is formed on the surface of the resist 47 as indicated by the solid line before partial heating. Thereafter, partial heating of the resist 47 causes an exposure area 48 of the image RA1W of the sub-scale RS1 to become a recess as indicated by the broken line, and a step 48a is formed in such a way as to enclose this recess. As the surface of the resist 47 after this partial heating is subjected to relative scanning in, for example, the Y direction with the probe 40 of the atomic force microscope 39 in FIG. 1, the atomic force microscope 39 provides the detection signal DS corresponding to the Y coordinate of the sample table 24 as shown in FIG. 6C. The detection signal DS shows tilt portions DS1 and DS2 corresponding to the contour of the main scale RM1 on the surface of the resist 47 and

tilt portions DS3 and DS4 corresponding to the contour of the image of the sub-scale RS1 on the surface of the resist 47.

Therefore, the alignment controller 36 detects a Y coordinate Y1A of the center of the tilt portions DS1 and DS2 of the detection signal DS, i.e., the center of the main scale RM1, and a Y coordinate Y1B of the center of the tilt portions DS3 and DS4, i.e., the center of the image of the sub-scale RS1, and acquires the amount of positional deviation, $\Delta WY1$, between those Y coordinates. Further, performing relative scanning with the probe 40 in the X direction yields the amount of positional deviation in the X direction, $\Delta WX1$, of the center of the image of the sub-scale RS1 with respect to the center of the main scale RM1.

Likewise, the amounts of positional deviation of the image of the sub-scale RS1 (or RS2) in the X direction and the Y direction with respect to the main scales RM2-RM6 ($\Delta WX2$, $\Delta WY2$), ($\Delta WX3$, $\Delta WY3$), ($\Delta WX4$, $\Delta WY4$), ($\Delta WX5$, $\Delta WY5$) and ($\Delta WX6$, $\Delta WY6$) are measured and those six the amounts of positional deviation ($\Delta WX2$, $\Delta WY2$) to ($\Delta WX6$, $\Delta WY6$) are supplied to the main control system 28. The main control system 28 performs EGA computation on those the amounts of positional deviation to acquire residual offsets (OX1, OY1), residual wafer scalings (WSX1, WSY1), residual wafer rotations (WRX1, WRY1), a residual intra-shot scaling SMAG1, and a residual intra-shot rotation SROT1. The difference between the biaxial residual wafer rotations WRX1 and WRY1 is equivalent to the wafer orthogonal degree. Those are errors including an error the alignment sensor 35 for a wafer mark has and an error in the base line amount measured as shown in FIG. 2. If the pattern image of the reticle R is exposed on each shot area on the wafer W in this state disregarding the factors of those errors, an overlaying error would occur.

To prevent this, the pattern image of the reticle R is exposed in order on the individual shot areas SA1-SAN on the wafer W in FIG. 5 while performing correction or the like of the position of the wafer W in such a way as to eliminate the individual residual errors. Specifically, at the time of aligning the wafer W, the residual offsets (OX1, OY1), residual wafer scalings (WSX1, WSY1) and residual wafer rotations

(WRX1, WRY1) are corrected by correcting the layout coordinates based on the coordinates obtained by correcting the layout coordinates of the individual shot areas on the wafer W, computed in the above-described wafer alignment, with the base line amount of the alignment sensor 35. The residual intra-shot rotation SROT1 is corrected by rotating at least one of the reticle stage 20 or the sample table 24 on the wafer stage side.

When exposure of the pattern image of the reticle R onto the entire shot areas SA1-SAN on the wafer W in FIG. 5 is completed, the images of sub scales (not shown) in the pattern area 45 similar to the sub-scales RS1 and RS2 of the reticle R in FIG. 4 have been exposed, approximately overlying one on the other, on the main scales RMA and RMB for registration measurement in each of the shot areas SA1-SAN. To evaluate the overlaying error of the actually exposed pattern image of the reticle R, m (m being an integer equal to or greater than 1 and desirably an integer equal to or greater than 3) shot areas are selected from all the shot areas SA1-SAN on the wafer W and two main scales RMA and RMB in those shot areas are taken as targets for measurement, before the exposed wafer W is changed to a next wafer to be exposed. At this time, one of the main scales RMA and RMB in the m shot areas may be taken as a target for measurement.

To change the latent images of the sub-scales to the undulation of the resist, a laser beam whose wavelength range has a low sensitivity is sequentially irradiated in a spot on the areas in the m shot areas where the main scales RMA and RMB are formed, by using the laser illumination system in FIG. 3. This raises the temperature of the portion which is irradiated with the laser beam to and above several tens of degrees, so that the image (latent image) exposed on the main scales RMA and RMB appears as the undulation of the surface of the resist. Thereafter, the undulation distribution of the resist provided by the main scales RMA and RMB and the sub-scale latent images thereon is sequentially measured in those selected m shot areas via the atomic force microscope 39, and the amounts of positional deviation between the m sets of main scales RMA and RMB to be measured and the corresponding sub-scale images, i.e., the

overlaying errors ($\Delta X1, \Delta Y1$), ($\Delta X2, \Delta Y2$), ..., ($\Delta X(2m-1), \Delta Y(2m-1)$), ($\Delta X2m, \Delta Y2m$) of the pattern image of the reticle R in the X direction and the Y direction at two measuring points in the m shot areas are acquired from the measuring results.

Using those amounts of positional deviation, the main control system 28 performs the same EGA computation as has been discussed above to acquire residual offsets (OX2, OY2), residual wafer scalings (WSX2, WSY2), residual wafer rotations (WRX2, WRY2), a residual intra-shot scaling SMAG2 and a residual intra-shot rotation SROT2. Note that when the number of the m shot areas to be measured is 1 or 2, not all of those residual errors are obtained. Even when the number of the shot areas is equal to or greater than 3, the residual errors in the shot cannot be acquired either if the number of measuring points in the shot is set to 1. However, at least the residual offsets (OX2, OY2) are measured under any condition.

Wafer exchange is performed after this measurement, and the next wafer to be exposed is placed on the wafer holder 23. Then, wafer alignment is carried out using the alignment sensor 35 in the same manner as was done for the first wafer, and parameters, such as the wafer scaling, wafer rotation, wafer orthogonal degree, offset and intra-shot rotation, of the to-be-exposed wafer in the stage coordinate system that is determined by the wafer-stage-side laser interferometer are computed. By correcting those parameters with the amounts of positional deviation between the main scales RM1-RM6 for registration measurement of the first wafer and the images of the corresponding sub-scales RS1 and RS2 and the residual errors (overlaying errors) measured for the m shot areas, new parameters are computed, the layout coordinates of the individual shot areas on the wafer are computed based on the new parameters, and the rotational angles of the like of the reticle and wafer are corrected as needed. Then, the wafer is aligned based on the calculated layout coordinates of and the pattern image of the reticle R is sequentially exposed on the individual shot areas on the wafer.

With regard to the second wafer, a laser beam is irradiated on the marks for registration measurement in the shot areas that are selected in the same way as those of the first wafer after exposure is completed, and the amounts of positional deviation

between the sub-scales of the latent images that have become the undulation of the resist and the base main scales are measured by the atomic force microscope 39 to thereby acquire the residual errors.

Thereafter, with regard to the third and subsequent wafers, alignment and exposure are carried out based on the results of correcting the results of the wafer alignment based on the amounts of positional deviation of the marks for registration measurement of the first wafer and the residual errors measured for the immediately previous wafer. This provides a high overlaying precision for each of one lot of wafers. What is more, for the second and subsequent wafers, as the atomic force microscope 39 is used only for the marks in the m shot areas selected from the individual shot areas on the wafer, the throughput does not significantly drop. Because the frequency of use of the atomic force microscope 39 is low, the deterioration of the probe 40 is small, making it possible to reduce the frequency of maintenance.

Even when the aperture stop plate 9 in FIG. 1 is rotated to change the illumination condition to annular band illumination, modified illumination or the like, information of the positional deviation of the projected image caused by the alteration of the illumination condition is included in the values of the amounts of positional deviation measured by using the atomic force microscope 39, so that a high overlaying precision is obtained.

The number of shot areas for measuring the marks for registration measurement by using the atomic force microscope 39 and the positions of the shot areas should not necessarily be the same for the individual wafers. For example, the residual wafer scaling can be measured alternately in the X direction and the Y direction and further the residual wafer rotation can also be measured alternately in the X axis and the Y axis by alternately selecting the measurement shot positions like two right and left shot areas in the first wafer, two up and down shot areas in the second one and two right and left shot areas in the third one.

The wafer that has exposed by the projection exposure apparatus in FIG. 1 undergoes the developing step, then undergoes a processing step for performing etching,

ion injection or the like with the resist pattern remaining after development used as a mask, and a resist removing step or the like of removing an unnecessary resist after the processing step. Then, the wafer process is completed by repeating the individual steps, such as exposure, development, processing and resist removal. When the wafer process is finished, a dicing step of dicing wafers printed circuit by printed circuit and making them into chips, a bonding step of applying wiring or the like to each chip, a packaging step of packaging each chip and so forth, are carried out in the actual assembling process, thereby finally manufacturing a semiconductor device, such as LSI.

The second embodiment of the present invention will now be discussed with reference to FIG. 7. In this embodiment, a measuring apparatus equipped with the atomic force microscope 39 in FIG. 1 is provided as separate from the projection exposure apparatus.

FIG. 7 shows a part of the exposure system according to this embodiment, and a projection exposure apparatus 51 and a measuring apparatus 54 are connected by a wafer transfer line 52 in FIG. 7. The projection exposure apparatus 51 has the structure of the projection exposure apparatus in FIG. 1 from which the atomic force microscope 39 and the laser illumination system in FIG. 3 are removed. The measuring apparatus 54 comprises the atomic force microscope 39 having the probe 40 in FIG. 1, an XY stage and a control apparatus for them.

In FIG. 7, a bake unit 53 for performing PEB (Post-Exposure Bake), pre-development bake, on the resist on the wafer exposed by the projection exposure apparatus 51 is arranged on the wafer transfer line 52 between the projection exposure apparatus 51 and the measuring apparatus 54. The operations of the projection exposure apparatus 51, the bake unit 53 and the measuring apparatus 54 are controlled by a host computer 55. A cable for direct transmission of data or the like or an infrared transmission line or the like may be provided between the control apparatus of the measuring apparatus 54 and the main control system of the projection exposure apparatus 51.

In this embodiment, when the projection exposure apparatus 51 performs

exposure on the first wafer, the projection exposure apparatus 51 sends information to the effect that an exposed wafer is carried out to the bake unit 53 and the measuring apparatus 54 either via the host computer 55 or directly. While the first wafer is moving on the wafer transfer line 52, the bake unit 53 performs post-exposure bake (PEB) on the resist on the wafer. As a result, the latent images of the sub scales on the main scales RMA and RMB for registration measurement in the individual shot areas in FIG. 5 become the undulation of the resist. The wafer that has passed the bake unit 53 reaches the measuring apparatus 54 where the amounts of positional deviation (residual errors) between the main scales for registration measurement and the images of the sub-scales in the m selected shot areas on the wafer are measured, and the amounts of positional deviation are sent to the main control system of the projection exposure apparatus 51 via the host computer 55 or directly.

The main control system computes the amount of correction for the results of the wafer alignment based on the supplied amounts of positional deviation and reflects this correction amount on the next wafer to be exposed. That is, based on the layout coordinates of that are obtained by correcting the results of the alignment of the next wafer, the alignment and exposure of the wafer are carried out. The control apparatus of the measuring apparatus 54 or the host computer 55 may calculate the correction amount for the results of wafer alignment from the amounts of positional deviation between the main scales for registration measurement and the images of the sub-scales and may send this correction amount to the main control system of the projection exposure apparatus 51.

When the projection exposure apparatus 51 receives information on the amounts of positional deviation (or correction amount) measured by the measuring apparatus 54, it is very likely that exposure for the second wafer has already started. In this case, the measuring results for the first wafer are fed back to the third wafer. This method does not lower the throughput in the projection exposure apparatus 51.

Further, when the results of measurement by the measuring apparatus 54 equipped with the atomic force microscope show that the residual errors of the first

wafer have exceeded predetermined tolerances, the wafer is sent out on a reprocessing line as a defective wafer to undergo resist removal and reapplication of the resist after which it is supplied again to the projection exposure apparatus 51. This eliminates the need for execution of a wasteful process and thus improves the yield of final products.

Instead of executing heating for transforming the latent images of the marks for registration measurement to the undulation of the resist by means of the bake unit 53, a laser illumination system similar to the one in FIG. 3 may be provided in the projection exposure apparatus 51 or the measuring apparatus 54 and may partially heat only the measuring area.

Although the images of the sub-scales are exposed on the main scales for registration measurement around a shot area and the amounts of positional deviation are measured prior to exposure of the first wafer in the first embodiment, this is troublesome and should not necessarily be carried out in this embodiment. Further, the number of shot areas for executing registration measurement and the layout thereof may be changed wafer by wafer in this embodiment too.

Further, wafers to undergo registration measurement need not be the whole wafers but such may be carried out at an arbitrary interval, such as every two other or every three other, in the above-described embodiments. Furthermore, measurement may be first performed wafer by wafer, after which the interval between wafers to be measured may be increased gradually. In addition, while monitoring how the residual errors change wafer by wafer, the interval between wafers to be measured may be increased if changes in the residual errors become smaller, and may be set smaller if changes in the residual errors become larger.

Although the atomic force microscope 39 is used as a shape inspecting system equipped with a probe in the above-described embodiments, the system need not necessarily be the atomic force microscope 39, and a scanning probe microscope (SPM) can be used. As one example of the shape inspecting system, a scanning tunneling microscope (STM) or the like may be used.

Although global alignment is used for wafer alignment in the above-described

embodiments, the present invention can also be adapted in the case of executing die-by-die alignment. Further, the exposure method and exposure system (exposure apparatus) or the like according to the present invention can be adapted not only to an exposure apparatus which uses light including X rays as an exposure beam as in the above-described embodiments, but also to a charged particle ray transfer apparatus which transfers or writes a predetermined pattern using charged particle rays, such as electron beam writing apparatus.

When an electron beam is used, for example, thermal electron discharge type lanthanum hexaboride (LaB_6) and tantalum (Ta) can be used for an electron gun. Further, the projection optical system is not limited to a reduction system but may be an equal magnification system or an enlarging system.

Furthermore, a high-frequency may be used as exposure illumination light. This high-frequency is acquired by amplifying a single-wavelength laser of an infrared range or a visible range which is emitted from a DFB semiconductor laser or a fiber laser by a fiber amplifier in which, for example, erbium (Er) (or both erbium and yttrium (Yb)) is doped, and then subjecting it to wavelength conversion to ultraviolet light by using a non-linear optical crystal.

The exposure apparatuses of the above-described embodiments are not limited to the user as an exposure apparatus for manufacturing semiconductor, but may be widely adapted to, for example, an exposure apparatus for liquid crystal which exposes the pattern of a liquid crystal display device on a rectangular glass plate and an exposure apparatus for manufacturing a thin film magnetic head.

The exposure apparatuses of the above-described embodiments can be manufactured by incorporating the illumination system and the projection optical system, which comprise a plurality of lenses, into the body of an exposure apparatus, performing optical adjustment, attaching a reticle stage and a wafer stage, which comprises multiple mechanical components, an atomic force microscope and a laser illumination system or the like as a heating system to the body of the exposure apparatus, making connection of wires or pipes, performing the optical adjustment as

explained in the above-described embodiments, attaching the reticle stage or wafer stage comprising multiple mechanical parts to the body of the exposure system, connecting wires and pipes, and performing general adjustment (electric adjustment, operational check, etc.). It is desirable that the manufacture of the exposure apparatus should be conducted in a clean room in which the temperature, degree of cleanness and so forth are controlled.

The present invention is not limited to the above-described embodiments, but may take various structures without departing from the scope of the invention. Further, the disclosures in Japanese Patent Application No. 10-83696 filed March 30, 1998, including the specification, claims, drawings and abstract, are incorporated herein by reference.

Industrial Applicability

The first exposure method of the present invention has such an advantage that because the amounts of positional deviation between the base positioning marks and the latent images of the exposed positioning marks are measured and the positional relationship between a predetermined pattern and the substrate is corrected based on the measuring results, the substrate to be exposed can be aligned with a high precision even when the illumination condition is changed to modified illumination or the like.

The second exposure method of the present invention has such an advantage that as the second substrate is aligned based on the amounts of positional deviation acquired by performing relative scanning to the first substrate with a probe, it is possible to reduce the frequency of use of the probe to avoid reduction of the throughput and to keep a high alignment precision.

According to the third exposure method of the present invention, it is possible to evaluate the actual overlaying errors (residual errors) of the image of that pattern.

The exposure system of the present invention can implement the exposure methods of the present invention. Further, as the fourth exposure system can heat a sensitive material at least partially, the position of the latent image of a to-be-detected

maker can be detected even if the sensitive material is a chemically amplification type resist. When the exposure apparatus and the detecting unit are separate units in the exposure system of the present invention, it provides an advantage such that there is no reduction in throughput in the exposure apparatus.

Because devices according to the present invention are manufactured by the exposure systems of the present invention that can use the exposure methods of the present invention, a high overlaying precision is obtained, so that high-performance devices can be provided.

CLAIMS

1. An exposure method for exposing a pattern on a mask where a first positioning mark is formed onto a substrate where a second positioning mark is formed on a non-shot area other than a shot area on which said pattern is to be transferred, the method comprising:

a first step of applying a sensitive material on said substrate;

a second step of setting an illumination area on said mask in such a way as to illuminate substantially said first positioning mark alone;

a third step of illuminating said mask to expose said first positioning mark onto said sensitive material on said non-shot area on said substrate;

a fourth step of heating at least a latent image portion of said first positioning mark of said substrate;

a fifth step of detecting an undulation distribution of said sensitive material by performing relative scanning to a surface of said sensitive material which was heated by said fourth step with a predetermined probe;

a sixth step of acquiring positional relation information of a latent image of said first positioning mark and said second positioning mark based on a result of the detection;

a seventh step of performing alignment of said pattern with said substrate based on said positional relation information; and

an eighth step of exposing said pattern onto said substrate after said alignment is completed.

2. (Cancelled)

3. The exposure method according to claim 1, wherein said positional relation information is an amount of positional deviation between said latent image of said first positioning mark and said second positioning mark.

4. An exposure method for exposing a pattern on a mask where a first positioning mark is formed onto a plurality of substrates on each of which a second

positioning mark is formed, the method comprising:

a first step of applying a sensitive material on each of said plurality of substrates;

a second step of exposing said first positioning mark onto said sensitive material on a first substrate in said plurality of substrates;

a third step of heating at least a latent image portion of said first positioning mark of said first substrate;

a fourth step of detecting an undulation distribution of said sensitive material by performing relative scanning to a surface of said sensitive material which was heated by said third step with a predetermined probe;

a fifth step, of acquiring positional relation information of a latent image of said first positioning mark and said second positioning mark based on a result of the detection;

a sixth step of performing alignment of a second substrate in said plurality of substrates which is different from said first substrate with said pattern based on said positional relation information; and

a seventh step of exposing said pattern onto said second substrate after said alignment is completed.

5. The exposure method according to claim 4, wherein an illumination area on said mask is so set as to illuminate substantially said first positioning mark alone between said first step and said second step.

6. (Cancelled)

7. The exposure method according to claim 4, wherein said second positioning mark is formed in a non-shot area on said first substrate which is other than a shot area where said pattern is to be transferred, and said first positioning mark is exposed onto said sensitive material in said non-shot area in said second step.

8. The exposure method according to claim 4, wherein said positional relation information is an amount of positional deviation between said latent image of said first positioning mark and said second positioning mark.

9. An exposure method for exposing a pattern on a mask where a first positioning mark is formed onto a predetermined substrate where a second positioning mark is formed, the method comprising:

a first step of applying a sensitive material on said predetermined substrate;

a second step of exposing said pattern and said first positioning mark onto said sensitive material on said predetermined substrate;

a third step of heating at least a latent image portion of said first positioning mark on said predetermined substrate;

a fourth step of detecting an undulation distribution of said sensitive material by performing relative scanning to a surface of said sensitive material which was heated by said third step with a predetermined probe; and

a fifth step of acquiring positional relation information of a latent image of said first positioning mark and said second positioning mark based on a result of the detection.

10. The exposure method according to claim 9, further comprising:

a fifth step of changing said predetermined substrate to another substrate which is different from said predetermined substrate and on which said second positioning mark is formed;

a sixth step of performing alignment of said another substrate with said pattern based on said positional relation information acquired in said fourth step; and

a seventh step of exposing said pattern onto said another substrate after said alignment is completed.

11. The exposure method according to claim 9, wherein said second positioning mark is formed in a shot area on said predetermined substrate in which at least said pattern is to be transferred, and said first positioning mark is exposed onto said sensitive material in said shot area in said second step.

12. The exposure method according to claim 11, wherein said pattern is exposed onto each of a plurality of shot areas on said predetermined substrate in said second step; and

an arbitrary one of said plurality of shot areas is selected and said latent image of said first positioning mark in said selected shot area and said second positioning mark are detected by performing relative scanning with said probe in said third step.

13. (Cancelled)

14. An exposure method for exposing a pattern on a mask where a first positioning mark is formed onto a substrate where a second positioning mark is formed, the method comprising:

a first step of applying a sensitive material on said substrate;

a second step of exposing said first positioning mark onto said sensitive material on said substrate;

a third step of heating at least a latent image portion of said first positioning mark on said substrate; and

a fourth step of detecting an undulation distribution of said sensitive material after said third step.

15. The exposure method according to claim 14, wherein an illumination area on said mask is so set as to illuminate substantially said first positioning mark alone between said first step and said second step.

16. The exposure method according to claim 14, wherein said second positioning mark is formed in a non-shot area on said substrate which is other than a shot area where said pattern is to be transferred, and said first positioning mark is exposed onto said sensitive material in said non-shot area in said second step.

17. The exposure method according to claim 14, wherein said second positioning mark is formed in a shot area on said substrate in which at least said pattern is to be transferred, and said pattern and said first positioning mark is exposed onto said sensitive material in said shot area in said second step.

18. The exposure method according to claim 16, further comprising:

a fifth step of acquiring positional relation information of a latent image of said first positioning mark and said second positioning mark based on a result of the detection;

a sixth step of performing alignment of said substrate with said pattern based on said positional relation information; and

a seventh step of exposing said pattern onto said substrate after said alignment is completed.

19. The exposure method according to claim 17, further comprising:

a fifth step of acquiring positional relation information of a latent image of said first positioning mark and said second positioning mark based on a result of the detection;

a sixth step of changing said substrate to another substrate which is different from said substrate and on which said second positioning mark is formed;

a seventh step of performing alignment of said another substrate with said pattern based on said positional relation information acquired in said fifth step; and

an eighth step of exposing said pattern onto said another substrate after said alignment is completed.

20. The exposure method according to claim 17, wherein said pattern is exposed onto each of a plurality of shot areas on said substrate in said second step; and

an arbitrary one of said plurality of shot areas is selected and said latent image of said first positioning mark in said selected shot area and said second positioning mark are detected in said fourth step.

21. An exposure system that exposes a pattern on a mask where a first positioning mark is formed onto a substrate where a second positioning mark is formed on a non-shot area other than a shot area on which said pattern is to be transferred and where a sensitive material is applied, the system comprising:

an exposure apparatus that has a light source illuminates said mask with illumination light, and an illumination area setting section arranged between said light source and said mask and sets an illumination area on said mask in such a way as to illuminate substantially said first positioning mark alone;

a heating unit that heats at least a latent image portion of said first positioning mark which was formed by said exposure apparatus on said sensitive material of said substrate;

a detecting unit that acquires positional relation information of a latent image of said first positioning mark exposed onto said non-shot area on said substrate and said second positioning mark by performing relative scanning to a surface of said sensitive material on said substrate which was heated by said heating unit with a predetermined probe; and

an alignment unit that electrically connected to said detecting unit and performs alignment of said pattern with said substrate based on said positional relation information.

22. The exposure system according to claim 21, comprising a substrate transfer line that arranged between said exposure apparatus and said detecting unit as a passage,

and transfers said substrate on which said first positioning mark is exposed by said exposure apparatus to said detecting unit.

23. The exposure system according to claim 21, wherein said heating unit is disposed on said substrate transfer line between said exposure apparatus and said detecting unit.

24. The exposure system according to claim 21, wherein said exposure apparatus has a projection system that projects said pattern onto said substrate; and said detecting unit is located in the vicinity of said projection system in said exposure apparatus.

25. The exposure system according to claim 24, wherein said heating unit is disposed in said exposure apparatus.

26. A predetermined device that manufactured by transferring and exposing said pattern onto said substrate by the exposure system as recited in claim 21.

27. An exposure system that exposes a pattern on a mask where a first positioning mark is formed onto each of a plurality of substrates on each of which a second positioning mark is formed and a sensitive material is applied, the system comprising:

an exposure apparatus that exposes said first positioning mark onto said sensitive material on a first substrate in said plurality of substrates;

a heating unit that heats at least a latent image portion of said first positioning mark which was formed by said exposure apparatus on said sensitive material of said first substrate;

a detecting unit that detects an undulation distribution of said sensitive material, provided by a latent image of said first positioning mark and said second positioning mark, by performing relative scanning to a surface of said sensitive material on said first substrate which was heated by said heating unit with a predetermined probe, and acquires positional relation information of a latent image of said first positioning mark and said second positioning mark based on a result of the detection; and

an alignment unit that electrically connected to said detecting unit and performs alignment of a second substrate different from said first substrate with said pattern based on said positional relation information,

wherein said pattern is exposed onto said second substrate after said alignment is completed.

28. The exposure system according to claim 27, comprising a substrate transfer line that arranged between said exposure apparatus and said detecting unit, so as to act as a passage that transfers said first substrate on which said first positioning mark is exposed by said exposure apparatus to said detecting unit.

29. The exposure system according to claim 28, wherein said heating unit is disposed on said substrate transfer line between said exposure apparatus and said detecting unit.

30. The exposure system according to claim 27, wherein said exposure apparatus has a projection system that projects said pattern onto said substrate; and
said detecting unit is located in the vicinity of said projection system in said exposure apparatus.

31. The exposure system according to claim 30, wherein said heating unit is disposed in said exposure apparatus.

32. The exposure system according to claim 27, wherein said second positioning mark is formed in a non-shot area on said substrate which is other than a shot area where said pattern is to be transferred, and said exposure apparatus exposes said first positioning mark onto said sensitive material in said non-shot area.

33. A predetermined device manufactured by transferring and exposing said pattern onto said plurality of substrates by the exposure system as recited in claim 27.

34. An exposure system that exposes a pattern on a mask where a first positioning mark is formed onto a predetermined substrate on which a second positioning mark is formed and a sensitive material is applied, the system comprising:

an exposure apparatus that exposes said first positioning mark onto said sensitive material on said predetermined substrate;

a heating unit that heats at least a latent image portion of said first positioning mark which was formed by said exposure apparatus on said sensitive material of said predetermined substrate; and

a detecting unit that detects an undulation distribution of said sensitive material, provided by a latent image of said first positioning mark and said second positioning mark, by performing relative scanning to a surface of said sensitive material on said predetermined substrate which was heated by said heating unit with a predetermined probe, and acquires positional relation information of a latent image of said first positioning mark and said second positioning mark based on a result of the detection.

35. The exposure system according to claim 34, comprising an alignment unit that electrically connected to said detecting unit and performs alignment of another substrate which is different from said predetermined substrate and on which said second positioning mark is formed with said pattern based on said positional relation information; and

in that said exposure apparatus exposes said pattern onto said another substrate after said alignment is completed.

36. The exposure system according to claim 34, wherein said second positioning mark is formed in a shot area on said predetermined substrate in which at least said pattern is to be transferred, and said exposure apparatus exposes said first positioning mark onto said sensitive material in said shot area.

37. The exposure system according to claim 34, comprising a substrate transfer line arranged between said exposure apparatus and said detecting unit as a passage for transferring said substrate on which said first positioning mark is exposed by said exposure apparatus to said detecting unit.

38. The exposure system according to claim 37, wherein said heating unit is disposed on said substrate transfer line between said exposure apparatus and said detecting unit.

39. The exposure system according to claim 34, wherein said exposure apparatus has a projection system that projects said pattern onto said substrate; and

said detecting unit is located in the vicinity of said projection system in said exposure apparatus.

40. The exposure system according to claim 39, wherein said heating unit is disposed in said exposure apparatus.

41. The exposure system according to claim 34, wherein said second positioning mark is formed in a non-shot area on said substrate which is other than a shot area where said pattern is to be transferred, and said exposure apparatus exposes said first positioning mark onto said sensitive material in said non-shot area.

42. A predetermined device manufactured by transferring and exposing said pattern onto said substrate by the exposure system as recited in claim 34.

43. An exposure system that exposes a pattern on a mask where a first positioning mark is formed onto a substrate on which a second positioning mark is formed and a sensitive material is applied, the system comprising:

an exposure apparatus that exposes said first positioning mark onto said sensitive material on said substrate;

a heating unit that heats a portion of said substrate where at least said first positioning mark is exposed; and

a detecting unit that detects an undulation distribution of said sensitive material, heated by said heating unit, and acquiring positional relation information of a latent image of said first positioning mark and said second positioning mark based on a result of the detection.

44. The exposure system according to claim 43, comprising a substrate transfer line that arranged between said exposure apparatus and said detecting unit, so as to act as a passage that transfers said substrate on which said first positioning mark is exposed by said exposure apparatus to said detecting unit.

45. The exposure system according to claim 44, wherein a heating unit is disposed on said substrate transfer line between said exposure apparatus and said detecting unit.

46. The exposure system according to claim 45, wherein said heating unit includes a baking unit for baking said sensitive material.

47. The exposure system according to claim 43, wherein said exposure apparatus has a projection system that projects said pattern onto said substrate; and said detecting unit is located in the vicinity of said projection system in said exposure apparatus.

48. The exposure system according to claim 47, wherein said heating unit is disposed in said exposure apparatus.

49. The exposure system according to claim 48, wherein said heating unit includes a laser device that irradiates a laser beam onto said substrate.

50. A predetermined device manufactured by transferring and exposing said pattern onto said substrate by the exposure system as recited in claim 43.

51. The exposure system according to claim 43, wherein said exposure apparatus can expose said pattern onto each of a plurality of shot areas on said substrate; and said detecting unit selects an arbitrary one of said plurality of shot areas and detects said latent image of said first positioning mark in said selected shot area and said second positioning mark.

52. (Cancelled)

53. (Cancelled)

54. (Cancelled)

55. A method of manufacturing an exposure system that exposes a pattern on a mask where a first positioning mark is formed onto a substrate on which a second positioning mark is formed and a sensitive material is applied, by assembling the following parts in a predetermined positional relationship:

an exposure section that exposes said first positioning mark onto said sensitive material on said substrate;

a heating section that heats a portion of said substrate where at least said first positioning mark is exposed; and

a detecting section that detects an undulation distribution of said sensitive material and acquiring positional relation information of a latent image of said first positioning mark and said second positioning mark based on a result of the detection.

56. The exposure method according to claim 14, wherein in said fourth step, said undulation distribution is detected by performing relative scanning to a surface of said sensitive material with a predetermined probe.

57. A device manufacturing method comprising a step of exposing said pattern formed on said mask onto said substrate using the exposure method recited in claim 14.

58. A device manufactured by the device manufacturing method recited in claim 57.

59. The exposure system according to claim 43, wherein in said detecting unit detects said undulation distribution by performing relative scanning to a surface of said sensitive material with a predetermined probe.